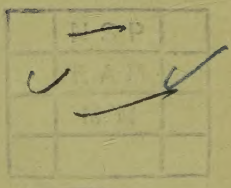
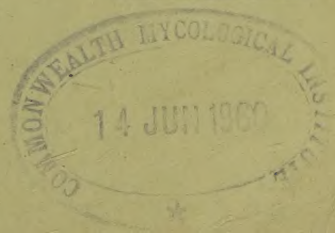
ANNUAL REPORT

of the

WEST AFRICAN COCOA RESEARCH INSTITUTE

1958-59





A POISONOUS INSECTICIDAL
SOLUTION HAS BEEN USED
IN BINDING THIS BOOK.

West African Cocoa Research Institute
Annual Report 1958-59

Errata

Page 28 Table 3 'c.m.' should read 'cm.'
Page 28 Table 3 'u' should read 'y'
Page 45 Table 11 'transplated' should read 'transplanted'

Land Clearance for Field Experimentation

Directional Felling of Secondary Forest (*see p. 52*)

ANNUAL REPORT

of the

WEST AFRICAN COCOA RESEARCH INSTITUTE

1958-59

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MANAGING COMMITTEE

At 31st March 1959

CHAIRMAN

*Acting Chief Secretary, West African Inter-Territorial Secretariat.

MEMBERS

*†Director, West African Cocoa Research Institute.

Chairman, Ghana Cocoa Marketing Board.

Mr K. A. Anane, Ghana.

Mr Osei Bonsu, Ghana.

*Permanent Secretary, Ministry of Food and Agriculture, Ghana.

*†Chief Agricultural Officer, Ghana.

Permanent Secretary, Ministry of Research and Information, Federation of Nigeria.

†Director of Agricultural Research, Federation of Nigeria.

Permanent Secretary, Ministry of Agriculture and Natural Resources, Western Region, Nigeria.

†Chief Agricultural Research Officer, Western Region, Nigeria.

Rev. E. T. Latunde, O.B.E., Nigeria.

†Director of Agriculture, Sierra Leone.

CO-OPTED MEMBERS (non-voting)

†Director of Agriculture, Eastern Region, Nigeria.

†Deputy Chief Agricultural Officer (Cocoa Industry), Ghana.

†Director of Agriculture, Southern Cameroons.

Manager, Messrs Cadbury & Fry, Ghana.

Manager, Messrs Rowntree-Fry-Cadbury, Nigeria.

†Deputy Director, West African Cocoa Research Institute.

†Deputy Director (Nigeria), WACRI Sub-Station, Ibadan, Nigeria.

Secretary, West African Cocoa Research Institute.

* Members of General Purposes Sub-Committee
† Members of Technical Sub-Committee

SENIOR STAFF

At 31st March 1959

TAFO STATION

Director	J. Lamb, O.B.E., M.SC., F.R.I.C., A.I.C.T.A.
Deputy Director	*C. G. Johnson, PH.D., D.SC., F.R.E.S., M.I.BIOL.
Scientific Assistant to Director	G. A. Jones, B.SC., A.I.S.
Secretary	H. L. Pugh, A.C.C.S.
Accountant	H. J. S. Mill, A.C.A.
Assistant Accountant	J. N. A. Hyde, A.C.C.S., A.A.I.A.
Office Assistant/Librarian	Miss D. J. Ellis
Entomologists	*C. G. Johnson
	†E. Dunn, B.SC.
	P. F. Entwistle, B.SC., A.R.C.S., F.R.E.S.
	M. R. Smith, PH.D., D.I.C., F.R.E.S.
	K. B. Armstrong, B.A., DIP.AG.SCI.
Plant Pathologists	J. W. Blencowe, PH.D.
	A. L. Wharton, B.SC., DIP.AG.SCI., D.T.A., M.I.BIOL.
	A. A. F. Brunt, B.SC.
	P. D. Turner, B.SC., M.I.BIOL.
	A. Attafuah, M.I.BIOL.
Plant Physiologist	R. G. Hurd, PH.D., M.I.BIOL.
Plant Breeder	D. R. Glendinning, B.SC.
Chemists	*R. H. Kenten, B.SC., A.R.I.C.
	R. K. Cunningham, B.SC.
Agronomists	T. H. R. Hall, B.SC.
	R. W. Smith, B.SC.
Statistician	C. de Jonge, L.I. (WAG.), A.R.N.S.A.S.
Laboratory Technicians (Electronics)	*A. J. H. Arnold, A.S.E.
(Spectrography)	J. C. Burridge, M.A., B.SC.
Medical Officer	P. K. K. Knudsen, CAND. MED. ET CHIR., D.T.M. & H.
Plantation Manager	H. W. S. Allison
Guide-Demonstrator	F. E. Decker
Station Manager	S. E. Ntim Kwafo
Maintenance Engineer	A. Maddison
Works Superintendent	E. K. Berko

* Seconded from Rothamsted Experimental Station

† Seconded from East of Scotland College of Agriculture

IBADAN SUB-STATION

DEPUTY DIRECTOR ..	T. W. Tinsley, B.SC., PH.D., M.I.BIOL.
ENTOMOLOGISTS	R. G. Donald, B.SC., A.I.C.T.A.
	C.K.H. Martini, PH.D.
PLANT PATHOLOGISTS ..	J. M. Thresh, B.SC., A.R.C.S.
	D. Kay, B.SC., M.I.BIOL.
	‡E. C. Hislop, B.SC., D.P.P.
CHEMIST	‡P. O. Park, B.SC., A.R.I.C.
AGRONOMIST	J. F. Longworth, M.SC.

‡ Seconded from Colonial Pesticides Research Unit, Arusha, Tanganyika

ADMINISTRATION

Managing Committee

Four meetings of the Managing Committee were held during the year:

24th (Special) Meeting was held on the 21st April 1958 at W.A.I.T.S., Accra.

25th (Special) Meeting was held on the 15th July 1958 at W.A.I.T.S., Accra.

26th Meeting was held on the 5th February 1959 at Tafo.

27th (Special) Meeting was held on the 9th March 1959 at Ibadan.

The special meetings held in 1958 were called for the purpose of obtaining authority to seal contract documents in connection with the erection of a house for the Deputy Director and of a Senior Staff Bungalow at WACRI, Ibadan. The special meeting held at Ibadan on the 9th March 1959 was called in connection with the Ghana Government's decision not to take over the Institute main station at Tafo and also to consider draft estimates for the WACRI Sub-station at Ibadan.

Finance

The Senior Accountant appointed to supervise the introduction of the new accounting system joined the staff at Tafo in June 1958 before proceeding on a short leave following his tour with W.A.I.F.O.R. He returned to Tafo in October and he and the Assistant Accountant proceeded to introduce the new system.

The Balance Sheet as at 31st March 1959 is shown at the end of the report.

Staff

Dr C. G. Johnson returned from leave on the 10th April 1958 and took up duties as Acting Director during the absence of the Director on leave.

Mr H. J. S. Mill joined the staff in June 1958.

Mr J. F. Longworth, Agronomist, was transferred from Tafo to Ibadan on 1st April 1958.

Mr P. O. Park, Chemist of the West African Fungicides Research Unit, arrived in Ibadan from Tanganyika on 24th April 1958. Dr P. K. K. Knudsen took up duties as medical officer on the 25th April.

The Director attended the 7th meeting of the Inter-American Cocoa Conference at Palmira, Colombia, in July, and also visited

the Instituto Interamericano de Ciencias Agricolas, Turrialba, La Lola Experimental Station for Cocoa, Costa Rica, and the Imperial College of Tropical Agriculture, Trinidad. He returned to Ghana on the 5th August.

Dr M. R. Smith and Mr K. B. Armstrong, Entomologists, Mr P. D. Turner, Mycologist, and Miss D. J. Ellis, Office Assistant/Librarian, joined the Staff during the months of July and August.

In February 1959 Mr E. Dunn arrived to take up his appointment as head of the Entomology Division in place of Dr C. G. Johnson.

Visitors

Both the main station and the sub-station at Ibadan were honoured by visits from a number of persons distinguished in a wide range of activities, including Science, Administration, Commerce and Politics. The staff appreciate the interest shown in their work and are stimulated by such interesting contacts.

Station Management

Residential Area and W.A.C.R.I. Village

In the Residential Area the site of the new bungalows and certain other areas were ploughed, harrowed and levelled for re-grassing so that mowing could be mechanised and labour requirements reduced. Ornamental shrubberies were planted in between the new buildings to screen them from each other. Contour drains were constructed in undulating areas to prevent soil erosion in the early heavy rains.

Monthly house spraying was carried out under the supervision of the Plantation Management Division.

Transport, Machinery and Implements

Four new vehicles—a Morris Pick-up, a Morris 3-ton truck, an Austin Omni-Van and an Austin Gipsy—were purchased. The Austin Gipsy was allocated to the Maintenance Division.

A Massey Ferguson 65 Tractor for heavy duties and a three-furrow disc plough were added to the field equipment.

Health

The Sub-Station, Ibadan, provided laboratory space for Dr S. G. Cowper of the University College Hospital to conduct a parasitological survey of Nigerian staff. Seventeen different parasites were found during this survey, rates of infestation by the various species varying from 1 per cent. to 58 per cent. of the volunteers examined. Dr Cowper hopes to continue this survey after his leave.

Cocoa Production

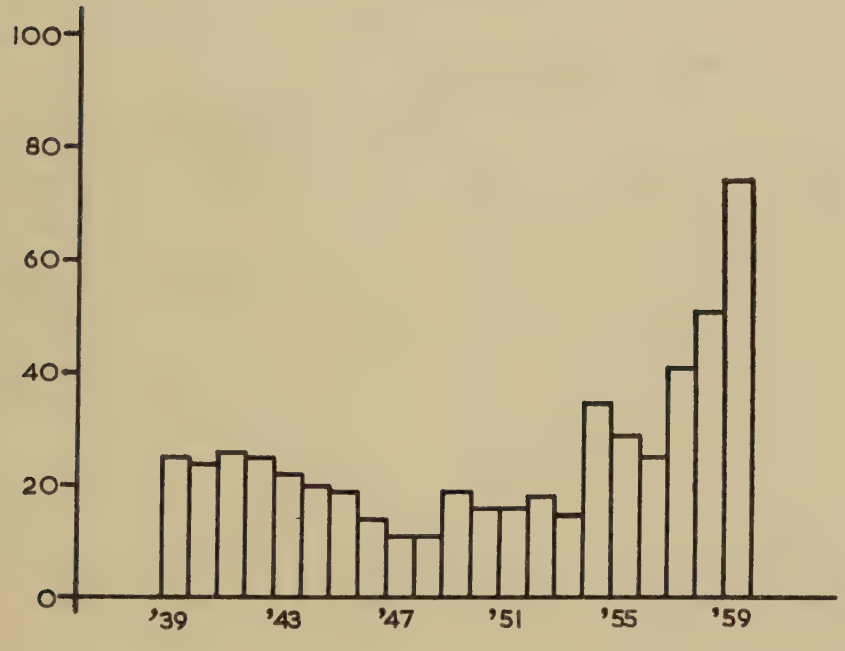
A total of 177,296 lb.* of dry cocoa was produced and 167,720 lb. was sold for £G10,380. This yield and the revenue represent an increase of 64,521 lb. and £G3,585 respectively, over those of the previous year. For the whole Station, 5.4 per cent. of the pods harvested were discarded as unfit for fermentation.

*Includes 2,760 lb. cocoa arising from pods purchased

W.A.C.R.I. COCOA SALES CHART

TONNAGE SOLD BY END OF EACH FINANCIAL YEAR

i.e., AS AT 31ST MARCH



Seed Distribution

A total of 78,835 F3 Upper-Amazon pods were distributed as seed. The recipients were Nigeria, Ghana, Cameroons and Sierra Leone.

Swollen Shoot Disease Incidence

The number of trees destroyed by swollen shoot disease has continued to fall. (*Rep. W. Afr. Cocoa Res. Inst.*, 1957–58, p. 16.) Four hundred and five infected trees were removed from the Old Station,

together with 588 infected seedlings. On the Square Mile 1,400 trees were removed, of which 200 were trees in contact with infected ones.

Clear-felling of a 35-acre Block

A 35-acre block of heavy secondary forest was clear-felled and about 6,500 tons of timber removed with minimum soil disturbance (see frontispiece). This was done by Plantation Management at a cost of only £G73 per acre. The area will be used for a large-scale shade and fertiliser experiment (p. 52).

Table A3

Figures for 1958 compared with 21-year means

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Highest Shade Maximum	21-year mean ..	93.1	93.8	93.1	93.9	92.2	89.0	86.9	86.7	88.0	90.5	90.5	90.7
	1958	92	95	94	96	91	87	85	91	87	90	91	92
Lowest Shade Minimum	21-year mean ..	59.2	62.0	66.1	66.7	67.0	66.2	65.7	65.1	67.0	66.9	65.8	62.7
	1958	65	65	69	71	70	68	61	61	69	68	70	65
Mean Relative Humidity (09.00 GMT)	21-year mean ..	86.4	83.9	82.1	80.9	81.8	85.1	86.0	85.9	85.4	83.4	81.3	84.3
	1958	87.8	86.3	83.2	81.2	83.2	87.1	82.3	82.7	86.7	83.4	82.5	84.1
Mean Relative Humidity (15.00 GMT)	21-year mean ..	55.9	53.4	56.9	59.8	64.5	70.3	70.6	69.4	71.3	72.5	65.9	61.7
	1958	64.6	61.5	62.6	66.9	69.6	77.5	67.9	64.3	71.5	69.7	66.2	61.1
Rainfall in inches	21-year mean ..	1.54	3.59	5.89	6.06	7.57	8.61	5.51	2.44	5.91	8.78	4.07	2.47
	1958	1.75	3.00	6.64	4.82	17.36	11.16	0.20	1.52	2.26	6.49	3.12	3.32
Number of Wet Days	21-year mean ..	3.8	6.9	11.9	11.1	14.0	18.9	13.6	12.7	14.5	18.7	11.2	6.2
	1958	7	8	15	9	15	20	5	5	9	20	17	7

Annual Rainfall (in inches) 1938–1958

1938-47 *Mean*	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	*21-Year Mean*
57.87	66.99	71.81	63.47	66.23	65.77	53.88	57.53	73.16	51.12	70.90	61.86	62.40

Monthly Rainfall (in inches) and Number of Wet Days, April 1958-March 1959

Month	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*March*
Rainfall in inches	4.82	17.36	11.16	0.20	1.52	2.26	6.49	3.12	3.32	0.29	2.08	9.84
Number of Wet Days	9	15	20	5	5	9	20	17	7	2	5	13

TAFO STATION

EXPERIMENTAL AREAS

TRIALS ON PLANTED COCOA

Agronomic Investigations

B1–Upper Amazon multiplication area.

B2–Upper Amazon spacing and pruning trial.

G4–Amelonado source trial.

H1–Second establishment trial.

J1–Amelonado spacing trial.

L2–Second Establishment trial. Amazon extension.

P2–Amelonado pruning trial.

H4(a)–Pilot Irrigation trial.

H5–Cover Crops and Mulches.

Botanical and Plant breeding investigations

A3–Clonal collection.

A5–Seedling growth experiment.

D5–9th Progeny Trial area.

D8–Clonal trial III

D9–9th P.T.A. Progenies.

I1–Seedling growth experiment.

M2–Clonal Trial I. (Ghana selections) Pod disease resistance trial.

N1–Trinidad Introductions in 1st 10 Acres.

N2–New Species area.

N3–Trinidad Introductions in 2nd 10 Acres.

N4–2nd Clonal.

N5–Multiplications (including T.100).

N6–Observational plots.

N7–Alphabetical plots 8th P.T.A. etc.

N8–Columbian Introductions. (Cultivated area only.)

N9–The New Trials F1, F2, F3, etc.

P1–Early bearing experiment.

P9–Variety Progeny comparison trial.

Pathological Investigations

A2–Collection of Material showing tolerance to Swollen Shoot Virus.

A4–Effect of inoculation with five different types of cocoa virus.

H2–Effect of inoculation with cacao swollen shoot virus on cocoa growing in the presence and absence of shade and fertiliser.

H3–Similar experiment to H2, but on Amazon cocoa.

Soil Science (Chemistry) Investigations

A6–Amazon Establishment on clear-felled land.

G1–Fertiliser trial: Rates of N, P, K, Mg.

G5–Fertiliser trial: 2^4, N, P, K, Mg, factorial.

I2 & F1–Establishment on exposed (Village) site.

K1–Shade and Fertiliser trial.

O1 & K2–Site for 30 acre fertiliser trial (to be planted 1959). The remainder of the planted areas including O.S. 1st to 7th Progeny trial.

Areas are harvested and maintained by Plantation Management Division.

TRIALS ON MATURE RANDOM-PLANTED COCOA

These areas are not delimited on the map.

Pathology:

EX1: Swollen Shoot Studies.

OSX1: 1st Black-Pod control Trial.

OSX2: 2nd „ „ „ „

OSX3: Susceptibility to Black-Pod disease.

Entomology:

BX1, GX1, FX1, IX1, JX1, MX1.

Ant-Mealybug trials and Marmara population survey.

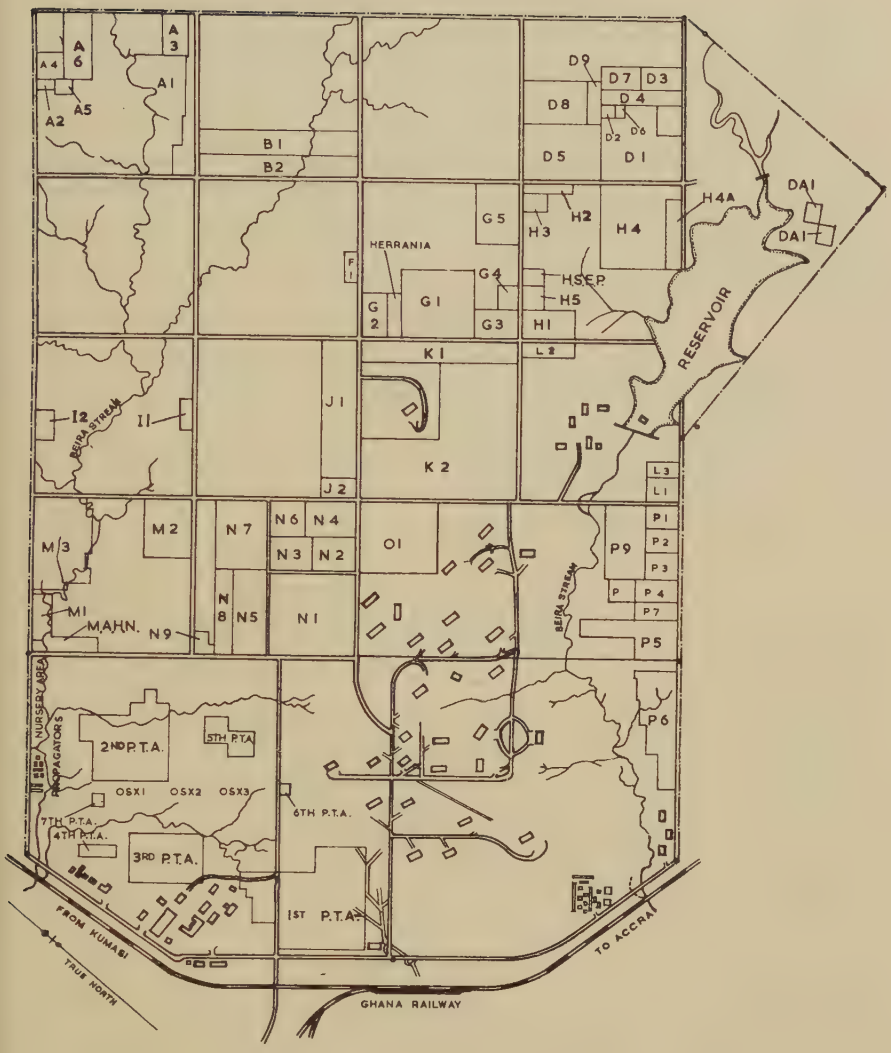
TRIALS NOT INVOLVING COCOA PLANTS

Soil Science:

H, S.E.P.: Soil Exposure plot.

Pathology:

M, A.H.N.: Alternative host nursery.


A 6
A 4
A 3
A1
A2
A5
B1
B2
D9
D7
D3
D8
D 4
D2
D6
D5
D1
DA1
DA1
H4A
H3
H2
H4
HERRANIA
G5
G4
G 2
G1
G3
HSEP
H5
H1
RESERVOIR
K1
L 2
I2
I1
BEIRA STREAM
J1
K 2
J 2
L 3
L 1
M2
M/3
N 7
N6
N4
N3
N2
O1
P1
P2
P3
P9
P
P 4
P7
P5
M1
MAHN.
N9
N 8
N5
N1
BEIRA STREAM
P6
NURSERY AREA
PROPAGATORS
2ND P.T.A.
5TH P.T.A.
OSX1
OSX2
OSX3
6TH P.T.A.
7TH P.T.A.
4TH P.T.A.
3RD P.T.A.
1ST P.T.A.
FROM KUMASI
TRUE NORTH
TO ACCRA
GHANA RAILWAY

VIRUS RESEARCH

CLASSIFICATION OF ISOLATES (A. Attafuah and A. A. Brunt)

Investigations into the differential transmission of thirteen cocoa virus isolates by nine species of coccids are progressing. This is an extension of the earlier work of Posnette (*Ann. appl. Biol.* **37**, 378, 1950) with the object of establishing further criteria on which a classification of cocoa viruses might be based. The results are tabulated in Table 1.

TABLE 1

Transmission of cocoa virus isolates by different vector species

VIRUS ISOLATE \ VECTOR SPECIES	*Pseudococcus njalensis* Laing	*Pseudococcus bukobensis* Laing	*Pseudococcus sp.* near *celtis* Strickland	*Pseudococcus sp.* near *gahani* Green	*Pseudococcus sconcavocerarii* James	*Planococcus citri* (Risso)	*Planococcus kenyae* (Le Pelley)	*Pseudococcus adonidum* L.	*Ferrisiana virgata* (Ckll)
New Juaben	+	+	+	+	+	+	+	−	+
Nkawkaw	+	+	+	+	+	+	+	−	+
Bosomtwe	+	+	+	+	+	+	+	−	+
Bosomuoso	+	+	+	+	+	+	+	−	+
Offa Igbo	+	+	+	+	+	+	+	−	+
Yakasse	+	+	.	.	.	+	.	−	+
Amafie	+	+	+	.	+	+	+	.	+
Bisa	+	.	+	.	.	+	+	−	+
Gandorhun	+	.	+	.	+	+	.	+	−
Mampong	+	.	+	+	+	+	+	+	−
Kpeve	+	+	+	+	+	+	+	+	−
Ad. 7	+	+	+	.	.	+	+	.	−
Alaparun	+	+	+	+	+	+	+	.	−
Cocoa necrosis virus (Asalu isolate) ..	−	.	−	−	.	−	−	.	−

. Result awaited

Pseudococcus adonidum L. has so far transmitted only the isolates Mampong and Kpeve which *Ferrisiana virgata* (Ckll.) has failed to transmit in a number of experiments. The other seven species have transmitted all the isolates with which they have been tested. These differences in vector specificity are of limited taxonomic use, for they do little more than separate the cacao swollen shoot virus complex from the cacao mottle leaf virus (*Rep. W. Afr. Cocoa Res. Inst.*, 1957–58, p. 23). There is still no means other than symptomatology in distinguishing between isolates within the swollen shoot complex.

None of the mealybug species used transmitted the cocoa necrosis virus from Asalu in Nigeria, the vector of which is still unknown (*Rep. W. Afr. Cocoa Res. Inst.*, 1957–58, p. 68).

THE HOST RANGE OF COCOA VIRUSES AND SYMPTOMATOLOGY

(A. Attafuah)

The herbaceous species *Corchorus aestuans* L. and *C. trilocularis* L. (Tiliaceae) have been infected with viruses of the cacao mottle leaf group. An exotic Tiliaceous species from Trinidad, *Muntingia calabura* L., has been infected with cacao swollen shoot virus.

It has been noticed that twigs and chupons of swollen shoot-infected cocoa trees are extremely brittle and will snap cleanly across their thickness, while healthy twigs break with a typically ragged 'greenstick fracture'. This 'brittle twig' symptom is so characteristic as to be a secondary diagnostic feature of the disease, the wood of the diseased twigs and chupons seems to be very desiccated when compared with healthy tissue.

THE INCIDENCE OF LATENT INFECTED TREES AT TAFO

(J. W. Blencowe)

The observations on 1,300 randomly-planted cocoa trees growing in uneconomic groups on Block E that were coppiced in 1958 (*Rep. W. Afr. Cocoa Res. Inst.*, 1957–58, p. 23), are now complete. Symptom-bearing shoots grew from the stumps of 95 out of 150 known infected trees, the remainder died. Fifty-seven out of 334 trees growing in contact with infected trees, and 93 out of 816 trees presumed to be healthy, produced infected chupons. Coppiced stumps in 38 per cent. of the 'contact' trees and 14 per cent. of the 'healthy' trees died; probably a considerable proportion of these trees that did not withstand coppicing were also infected.

These results suggest the need for further work on the latent period of this type of virus. Observations on infected trees of the same age and growing in the same place show that the rate of decline of infected trees is rapid. Trees are moribund within eighteen months of the first appearance of symptoms, even though capsid injury is kept to a minimum. It is thus difficult to believe that the masked infections discovered by coppicing apparently healthy trees are latent infections with mild strains of virus. Unless mild viruses are mutating to severe ones at irregular intervals, they must be recently infected trees. Trees infected by patch-grafting with infected tissue usually show symptoms of infection with the local strain of swollen shoot virus in about four months.

RESISTANCE AND TOLERANCE (J. W. Blencowe and A. Attafuah)

The tests of clonal cuttings of fifty T17 parents for tolerance to infection with viruses have shown that there is no correlation between degree of tolerance to the New Juaben isolate of swollen shoot virus and to the un-related Kpeve isolate of the cacao mottle leaf virus. There were certain parent lines that were quite tolerant to both viruses, and these were amongst the ones chosen for inter-pollination so that the progenies could be tested. The first batches of seeds from these crossings were infected at the bean stage in an experiment designed to measure their resistance to infection. None of the progenies were extremely resistant but several will probably provide useful parent material in the future. The crossings are being repeated this year and the more promising ones will be tested for tolerance in the seedling stage. A field experiment (E1) has been planted with progeny of a series of Nanay, Parinari and Iquitos crosses. This experiment is designed to compare the resistance and tolerance of the progenies to virus infection under field conditions. When the trees have grown sufficiently to form a continuous canopy, the guard rows between the plots, which are West African Amelonado, will be infected with a severe strain of swollen shoot virus. The virus will be allowed to spread unchecked through the experiment. This should yield information both on the field resistance to infection of the plants, and on the effects on growth and yield. An experiment using similar cocoa seedlings has also been planted in Nigeria.

THE EFFECT OF VIRUSES ON GROWTH AND YIELD OF COCOA
(J. W. Blencowe and A. A. Brunt)

A series of field experiments has been commenced to study the effects of virus-infection on the growth and yield of in-bearing cocoa trees. It is hoped that these will give some information on the cause of mortality of virus-infected trees in Ghana; particular attention will be paid to the role of capsid-injury in the eventual death of infected trees. The experiments fall into two groups, those in which trees are being artificially infected, and those where observations are being made on naturally occurring outbreaks of virus. The artificially inoculated experiments are being made at W.A.C.R.I., in conditions where capsid injury is being reduced to a minimum over the total experimental area by regular treatment with insecticide.

The first experiment compares trees graft-inoculated with five viruses with healthy controls. The trees are young Amelonado, just coming into bearing. The viruses tested are a severe swollen shoot isolate of the New Juaben type, an isolate from Dawa closely related to the more severe New Juaben type, cacao mottle leaf virus from

Kpeve, a mild isolate from Worawora that causes only swellings, and a relatively severe virus of the swollen shoot complex from Bosomuoso in Western Ghana (which is not immunologically related to the New Juaben isolate). The experiment is arranged in a 6×6 Latin Square with fourteen trees per plot.

The second experiment is designed to study the effect of infection with a severe swollen shoot virus on trees grown in the presence and absence of an application of a compound fertiliser. The design is a 2^2 factorial one with each treatment combination replicated six times on plots of eight trees each. The complete experiment is itself replicated on Amazon and Amelonado cocoa each growing with and without shade, making a total of ninety-six plots in all. In each case the cocoa is young and has recently come into bearing.

The second group of experiments, which are being made with the co-operation of the Division of Agriculture, studies the effect of routine capsid-spraying on the yield and growth of trees infected with swollen shoot virus. The experiments will be of two kinds, some will be in places at the edge of the main area of virus spread in the Eastern Province and the treated and untreated plots will be arranged so that about 20 per cent. of the trees are infected at commencement of treatment. It will thus be possible to observe the spread of infection and subsequent decline in vigour of the trees in the presence and absence of capsid injury. The plots will each contain about 300 trees of randomly-planted Amelonado cocoa. About a dozen pairs of plots of this type are planned, mostly in the centre of the Eastern Province. The second type of experiment is being made on plots of totally infected cocoa growing in remote areas of the Eastern Province and in the West of Ghana. The viruses in these cases will, of necessity, be less virulent than those in the previous group of experiments, for it is difficult in the Eastern Province to find compact areas of 300 infected, but still living, trees; in most outbreaks of that size the infected trees would be distributed in a narrow perimeter around areas of dead trees.

A VIRUS DISEASE OF COCOA IN SIERRA LEONE

(A. Attafuah and J. W. Blencowe)

An outbreak of virus disease in cocoa was discovered in 1958 during a reconnaissance survey of about 100 peasant farms in Sierra Leone. The virus has been transmitted from diseased to healthy cocoa seedlings by grafting and by mealybugs, and is the first recorded virus disease of cocoa in that country. Thirty-seven infected trees were found in April 1958, but by December the number had increased to fifty-six. The naturally infected plants showed a mosaic pattern on

some of their leaves, but no stem-swellings have been found. In April 1958 the canopy of the infected trees appeared to have deteriorated and there was an increased weed-growth in the forest litter beneath them, but in December this was not so noticeable, and symptoms of infection were more difficult to see. Symptoms in experimentally infected seedlings were mild, with a reduction in growth-rate, and a mosaic pattern on some leaves together with slight stem-swellings. The virus is similar in symptoms to a number of the mild viruses isolated from cocoa in other parts of West Africa, but there is not yet any definite evidence of relationship.

The outbreak is in the Gandorhun district of eastern Sierra Leone on the west bank of the Moa River. The cocoa farm is of about 6 acres isolated from other cocoa by coffee and other crops. The infected trees are grouped about the foot of a very large *Ceiba pentandra* tree that serves as a landmark for the ferry that crosses the river at that point. In addition to seven other Ceibas, three specimens of *Sterculia tragacantha* Lindl. were found growing on the farm. These were the only species present that are known to be susceptible to infection with cacao swollen shoot virus in Ghana. *Cola nitida* Schott. & Endl. was plentiful, and another member of the Tiliales, *Glyphaea brevis* (Spreng) was present; neither of these are susceptible to the swollen shoot virus complex in Ghana, but must be tested for susceptibility to this virus.

The virus outbreak may have originated from infected plant material carried in along the trade-route to and from nearby Liberia which crosses the river here, but it is more likely that it has arisen from a naturally occurring infection in the large *Ceiba*, which must be of considerable age.

The virus discovered does not appear to be very destructive, moreover, the discontinuous distribution of the cocoa farms in the country and the relative scarcity of the vector mealybugs should make for a slower rate of spread than in some other parts of West Africa.

'CUSHION-GALL' DISEASE OF COCOA

(A. A. Brunt)

A disease causing gall-like proliferations of the flower-cushions of cocoa trees has caused serious damage to plantations in Central America. The proliferations, which bear an excessively large number of flowers, are at first green and soft, but later become hard and woody with a convoluted surface. A similar disorder was first reported in Ghana by Dade (*Crop Diseases in the Gold Coast*, p. 33, 1935), and a survey has been made, with the aid of the Division of Agriculture, to assess its present importance. Cushion galls were found very

occasionally in only ten localities; it is assumed that as the disorder is not any more plentiful than it was a quarter of a century earlier, it is unlikely to be of economic importance in Ghana. The cause of the disorder is still unknown.

BLACK-POD DISEASE

SPRAYING TRIALS AGAINST *PHYTOPHTHORA PALMIVORA* BUTL.

(A. L. Wharton)

Three new field experiments on the chemical control of 'black-pod' were started in 1958. The first (OSX1) has a factorial design testing the value of all combinations of spraying with Carbide-Bordeaux mixture in early, mid- and late season. The primary object is to discover whether spraying during the mid-crop outbreak only was effective in preventing an epiphytotic later in the year on the main crop. The second (OSX2) with a randomised block design, is to study the possible nutrient effects of fungicidal sprays. The treatments include applications of 1 per cent. copper sulphate to the canopy and as a soil dressing, and Carbide-Bordeaux mixture and Perenox sprayed against pod disease. The third experiment is a small one to find the response to a copper fungicide when a general fertiliser dressing has been applied to the cocoa.

Levels of black-pod disease in Ghana were low during 1958 and the incidence on control plots in these trials was negligible. In experiment OSX2 the only differences in yield was reflected in the records of pre-treatment years. All the trials are continuing for a second year.

There are still no indications from these trials, or others conducted by the Division of Agriculture during 1958, that spraying against black-pod disease would be profitable in Ghana under present conditions. However, the continued extension of improved methods of farming such as chemical control of capsid pests, the planting of improved selections, shade management and the possibilities of applying fertilisers is resulting in large yield increases and, therefore, more pods exposed to infection and loss. At Tafo, the Amelonado Spacing Trial has recently given very high yields, as much as 2,000 lb. of dry cocoa per acre on some treatments. Shade has now been completely eliminated and a fertiliser dressing applied to maintain or increase this yield. Records of black-pod disease are being taken to study the incidence on cocoa growing at different spacings and different levels of productivity. At the same time data is being collected from as many experimental units as possible for which yield increases over a number of years have been demonstrated. So far five years' records from eleven Division of Agriculture capsid control units in the Eastern Region have been analysed. The regression line for all the data shows

an expected average increase of 290 black-pods for each rise of 1,000 in the total numbers of fruits per acre. The slope of the lines for each year's records is similar, showing that the relationship is independent of annual fluctuations in levels of pod disease on these units.

POD SUSCEPTIBILITY EXPERIMENT (A. L. Wharton)

Records for previous years (cf. *Rep. W. Afr. Cocoa Res. Inst.*, 1957–58, p. 25) have shown the importance of infections on cherelles during the early season outbreak. It is known that this epiphytotic is followed by continued periods of physiological wilt. The problem of whether or not diseased cherelles would have reached maturity without wilting if protected from *Phytophthora* attack by, for example, chemical spray control, was investigated in 1958. The recorded trees were split into pairs and fruits on one tree in each pair protected from *Phytophthora* infections by weekly spraying with 2 per cent. Perenox. Analysis of the results showed that the high concentration of fungicide used, although fulfilling its purpose in eliminating spore infections, had, in fact, increased the numbers of cherelles lost from physiological wilt. The lower incidence of wilt on control compared with treated trees could not, therefore, be fully accounted for by the larger number of cherelles attacked by the pathogen. Cherelle infections on the trees used for the control treatment in 1958 varied considerably between each of the three years, 1956–58. Using this data, there are indications that *Phytophthora* attack on young cherelles is accompanied by a reduction in the number of cherelles which subsequently wilt.

SOURCES OF INFECTION BY *PHYTOPHTHORA PALMIVORA* (P. D. Turner)

Isolations from a number of sources have been made in an attempt to assess their relative importance as potential disease inocula in the field.

Cocoa pod-husks

Scrapings from the exterior of fifty husks found on trees were wound-inoculated into healthy pods, four inoculations were made from each pod-husk. A further 200 inoculations were made with scrapings from the interior of the husks. No development of *P. palmivora* was recorded from the external inocula, and only one lesion from the interior. However, nearly all inocula were found to infect pods, although at a much slower rate than *P. palmivora*, chiefly by species of *Fusarium* and *Botryodiplodia theobromae* Pat., and in one instance by *Trachysphaera fructigena* Tab. & Bunt. Twenty-six healthy pods buried

in old husk heaps also failed to develop any lesions of *P. palmivora*. These observations confirmed those of Dade (*Dept. Agric. Gold Cst. Year Book*, **23**, 122, 1930). Old husks are considered to be of very little importance in 'black-pod' epiphytology, fresh husks, however, both healthy and diseased, may well be significant (*vide infra*).

Trunk and foliage

Monthly samplings over a period of eight months of foliage washings, bark, and detritus collected in crevices, branch junctions, etc., have been made. *P. palmivora* has been isolated irregularly on three occasions from foliage, twice from detritus and once from bark, indicating that these sources are only of incidental and probably lesions from which *T. fructigena*, *B. theobromae*, *Pestalotiopsis* sp. and *Fusarium* spp. were isolated, and the trunk may be an important source of inoculum of wound-infecting fungi. Only occasional lesions caused by other fungi developed from leaf inocula. Investigations are being continued.

Other host plants

Diseased tissues, mainly from fruits, from the fifty-eight plants listed in Table 2 have been tested as possible alternative sources of *P. palmivora*.

Two samples, *Gmelina arborea* and *Herrania* sp., yielded *P. palmivora*. The fruits of *G. arborea* were found to be heavily infected with *P. palmivora* throughout the early months of crop production and these may provide an inoculum source of local importance where *G. arborea* is used as a shade tree. So far as is known, *P. palmivora* has not previously been recorded on *Gmelina*.

Soil

The soil has been found to be a source of *P. palmivora*, and the work of Wharton (*Rep. W. Afr. Cocoa Res. Inst.*, 1953–54) has been continued. Isolations from seven sites of different soil types have been made by partly burying healthy pods in the ground. Lesions of *P. palmivora* were found to occur irregularly despite the apparently widespread distribution of the fungus: this was probably caused by the random and unequal distribution of infective propagules, both between and within the sites. The influence of a fungistatic factor was almost certainly important in conjunction with soil moisture (*vide infra*). Regular soil sampling is being continued.

Table 2

Species tested for natural infection with P. PALMIVORA

Lauraceae

Persea gratissima Gaertn.

Myrsticaceae

Pycnanthus angolensis Welw.

Caricaceae

Carica papaya Linn.

Guttiferae

Mammea africana Sabine.
Pentadesma sp.

Tiliaceae

Desplatsia chrysochlamys (Mildbr. & Burret).
Desplatsia dewevrei (De Wild. & Th. Dur.) Burret.
Desplatsia subericarpa Bocq.
Muntingia calabura (exotic)

Sterculiaceae

Cola gigantea var. glabrescens Brenan & Keay
Cola millenii K. Schum.
Herrania sp.
Leptonychia pubescens Keay.

Bombacaceae

Bombax buonopozense P. Beauv.

Euphorbiaceae

Alchornea cordifolia Schum. & Thonn.
Discoglypremna caloneura (Pax.) Prain.
Elaeophorbia drupifera (Thonn.) Stapf.
Jatropha curcas Linn.
Macaranga hurifolia (M. huraefolia) Beille.
Microdesmis puberula Hook. f. ex Planch.

Mimosaceae

Parkia filicoidea Welw.
Piptadeniastrum africanum (Hook. f.) Brenan.

Papilionaceae

Cajanus cajan Linn.

Moraceae

Artocarpus incisa Linn.
Ficus capensis Thunb.
Musanga smithii R. Br.
Treculia africana Decne.

Pandaceae

Pandanus candelabrum Beauv.

Balanophoraceae

Thonningia sanguinea Vahl.

Irvingiaceae

Irvingia gabonensis Baill.

Ampelidaceae

Leea guineensis G. Don.

Sapindaceae

Blighia sapida Konig.
Blighia unijugata Bak.
Chytranthus talbotii (Bak. f.) Keay.
Paullinia pinnata Linn.

Anacardiaceae

Mangifera indica Linn.

Connaraceae

Cnestis ferruginea DC.

Ebenaceae

Diospyros sanza-minika A. Chev.
Diospyros sp.

Sapotaceae

Omphalocarpum ahia A. Chev.

Apocynaceae

Thevetia neriifolia Juss. ex Steud.

Rubiaceae

Coffea arabica Linn.
Randia maculata DC.
Randia macrantha DC.
Schumanniophyton magnificum Harms.

Solanaceae

Capsicum annuum Linn.
Solanum incanum Linn.
Solanum torvum Swartz.
Solanum verbascifolium Linn.

Bignoniaceae

Newbouldia laevis Seem.

Verbenaceae

Clerodendron capitatum Schum. & Thonn.
Gmelina arborea Roxb.
Lantana Camara Linn.
Stachytarpheta jamaicensis Vahl.
Vitex grandifolia Gurke.

Marantaceae

Hybophrynium Braunianum K. Schum.
Marantochloa holostachya Hutch.

Of other fungi isolated during the course of the investigation *Cylindrocladium scoparium* Morg., apparently hitherto unrecorded in Ghana, occurred most frequently, causing rapidly-spreading lesions characterised by a soft texture, irregular margins, depressed centre and copious spore development. *Botryodiplodia theobromae* and *Fusarium* spp., were also frequently isolated.

SAPROPHYTIC ACTIVITY OF *PHYTOPHTHORA PALMIVORA*

(P. D. Turner)

Experiments other than in diseased pods have shown that *P. palmivora* is capable of very limited saprophytic development. Samples of seven different soils, both sterile and unsterile, were placed in Petri plates and inoculated with pieces of infected pods that served as food bases. Inoculations taken at measured distances from the diseased tissue showed that the fungus spread up to 0.5 cm. into the surrounding soil. This occurred in most soil types. No further development had taken place after eighty days, even though the inocula remained viable.

It was apparent from these observations that development of *P. palmivora* in soil, other than from a food base, was inhibited. Although isolations of *P. palmivora* have been made from soil on several occasions in different West African territories, it has remained unknown whether spore germination and further development as a soil saprophyte occurred, or whether the fungus existed in a quiescent state. Thorold (*Trans. Brit. mycol. Soc.* **38**: 435, 1955) suggested the possible presence of a fungistatic factor in Nigerian soils, and this has been found at W.A.C.R.I. Demonstration of fungistasis by the usual techniques employing cellophane squares and dialysis tubing were unsatisfactory owing to the difficulty of maintaining conditions favourable for zoospore production. Aqueous extracts of eight different soil types allowed copious zoospore production and germination in Petri plates, and occasionally development was superior to that of spores in control plates of de-ionised water. Unusual spore types were occasionally found: these were intermediate in size between zoospores and chlamydospores, non-motile, formed by division of the sporangial cell contents, and were bounded by a wall thinner than that of a normal chlamydospore. Ether extracts of soils, however, showed marked fungistatic properties. Of the eight soil types tested, sand from a drainage channel in a cocoa plantation showed least inhibitory properties, and of the remaining seven loam soils one extract showed only partial reduction of zoospore germination, although the spores on release were less active than control spores. Spores in extracts of two soils germinated directly after two days, and those in the remaining soil solutions failed to develop.

It was found possible to break the fungistatic effect by addition of aqueous pod extracts to the soil solution. In addition, moisture drops collected from pods in the field were found to stimulate spore germination. This suggests that soil splashes are a major source of inoculum of *P. palmivora*, particularly in initiation of disease outbreaks.

Other experiments on longevity of spore viability in the same soils have shown the effect to be fungistatic and not fungitoxic. Separate sporangial and zoospore inocula have been found to be viable for at least 120 days in some soils. Preliminary experiments have revealed that survival of zoospore suspensions, obtained free from sporangia by filtration through Whatman No. 1 filter paper, is dependent on both the soil type and the moisture content of the soil, with only a very short survival period in soils containing 0 and 100 per cent. of their moisture holding capacity.

Competition for healthy tissue in soil is also being investigated. Experiments with unsterile soils to which sporangia of *P. palmivora* had been added demonstrated that the fungus was a highly competitive saprophyte when green pod material was made available. This observation has some bearing on the disposal of pods after breaking, for although old husks were found to be insignificant sources of disease, it is possible for fresh pod material to become a focus of highly infective material for a limited period. Experiments on this problem are being continued.

RESISTANCE AND TOLERANCE (A. L. Wharton)

Field recording of diseased fruits on the 1st Clonal Trial has now ceased and an analysis of the two years' data completed by Mr de Jonge. The policy in 1958 was to compare the different selections at lower levels of infection. 'Black-pods' were, therefore, removed as they were recorded and not labelled and left on the trees as sources of inoculum, as was the practice in 1957. The two years' data confirmed highly significant differences in levels of *Phytophthora* infections between many of the Trinitario selections included in the trial. When total infections, including those on cherelles are corrected for total yield of the different selections the most 'susceptible' variety, A12 had 1,687 'black-pods' recorded compared with 111 and 79 for the most 'resistant' clones, ACU85 and S27, respectively. Self and cross pollinations have been made with a view to planting a specific pod disease resistance trial in 1960 to study the inheritance of field resistance from the clonal parents. Negotiations have started to plant the trial on the high scarp at Mpraeso in an area where the farms are virtually abandoned by their owners due to destruction of the crop following black-pod disease.

Two years' detailed records of pod disease have now been collected for the 2,000 individually recorded trees in the 9th Progeny Trial which includes hybrids with Amazon parentage. The trial bore its first substantial crop in 1958 and is not yet in full bearing. It is proposed to collect one further year's data before assessing the selections for susceptibility and investigating any segregation for resistance within the progeny.

Records of differential susceptibility to pod disease have started on the 2nd Clonal Trial (one Amelonado and nineteen Trinitario types) and on the five blocks of the 2nd Progeny Trial least damaged by virus losses and poor environmental conditions. This trial includes progeny from clonal parents already tested and under investigation.

There is no close fit between the tolerance rankings (as measured by lesion growth following wound inoculation) of selections in the 1st Clonal Trial and the rankings for field resistance and it is not possible to screen other selections for resistance by the simple test for tolerance. For tolerance tests it is only necessary to measure length of the lesion and variation is reduced if tests are made on pods on trees, rather than on detached fruits in the laboratory. Selections in the 1st Clonal and 9th Progeny Trials were also tested for tolerance to bark infection. Measurements of lesions in the bark and wood were made at two and four monthly intervals following wound inoculation. Irregularities in the shape of lesions and variations in lesion length within selections rendered this method unsatisfactory using samples of five or ten branches per selection.

STRAINS OF *PHYTOPHTHORA PALMIVORA* (P. D. Turner)

In continuation of the work of Wharton described in the previous Annual Report, p. 28, 1957–58, a further twenty-eight isolates of *P. palmivora* from widely-spaced localities in Ghana have been examined. Comparison of rates of lesion development in artificially-infected pods showed two isolates which grew at a slower rate than the remainder. Spore measurements of individual isolates were too variable to be of value in delineating possible strains, but from the limited data available it seems probable that some geographical variation in spore size is present. No differential response to inoculation into other hosts was found, and all isolates were found to attack, to a greater or lesser degree, the following plants: *Capsicum annuum*, *Carica papaya*, *Citrus aurantiaca*, *C. medica* var. *limonum*, *Cola millenii*, *Ficus capensis*, *Gmelina arborea*, *Herrania* sp., *Hibiscus esculentus*, *Lycopersicum esculentum*, *Mangifera indica*, *Persea gratissima*, *Pseudospondia microcarpa*, *Psidium guajava* and *Solanum incanum*. Isolates of *P. palmivora* from *G. arborea* and *Herrania* mentioned above were apparently

identical with the pathogen isolated from cocoa. Preliminary tests suggest that isolates differ in their response to artificial media containing various polyphenols, indicating a possibly useful technique for differentiating between strains.

Limited comparison of isolates of *P. palmivora* from other West African territories has been made. Isolates from Sierra Leone, Ivory Coast and one from Nigeria appeared similar to the Tafo isolate, but another from Nigeria and one from the British Cameroons were very different. The latter isolates differed in appearance both in pods and in artificial culture, showed much slower growth rate, had less elongated spores and failed to infect a number of alternative host plants. These isolates are considered to be a distinct strain from that in Ghana, varying markedly in virulence. The relevant data are summarised in Table 3.

TABLE 3

Comparison of isolates of P. PALMIVORA *from West Africa*

Isolate	*Av. length + width lesion size (c.m.)* 5 days	*Av. spore length u*	*Length: width ratio of spores*
Tafo	21.9±1.4	43.1±2.5	1.7
Sierra Leone ..	22.2±1.2	41.8±2.8	1.7
Ivory Coast ..	22.6±1.3	42.9±2.8	1.7
Nigeria A ..	21.2±1.4	43.5±2.8	1.7
Nigeria B ..	0.0	38.1±2.1	1.2
Cameroons ..	0.0	41.4±2.6	1.4

APPARENT INFLUENCE OF VIRUS INFECTION ON DEVELOPMENT OF *PHYTOPHTHORA PALMIVORA* POD LESIONS (P. D. Turner)

Large green pods of the 1958–59 harvest from 'Amelonado' trees, each infected artificially with one of four distinct cocoa virus isolates, were inoculated in replicates of twenty with *P. palmivora*, and the resulting size of lesions compared with those in pods from virus-free control trees. The viruses used were three isolates of cacao swollen shoot virus (New Juaben Mild and Severe, and Bisa) and one of cacao mottle leaf virus (Kpeve). The trees had been infected by grafting eleven months earlier, and infection subsequently confirmed by mealybug transmission tests. Inoculation of the fungus was standardised by using a cork borer to remove a tissue disc from each pod and filling the cavity with an equal-sized piece of fungus culture on oatmeal agar. Development took place at room temperature in previously-sterilised humid chambers of polythene sheeting over wire

frames. Record was made of the daily increase in lateral and longitudinal spread of each lesion, measurements being taken along the same marked diameters on every occasion.

Comparison by analysis of variance (by Mr. de Jonge) of the average of length plus breadth lesion measurements made after five days showed that there were significant differences ($p=0.05$) both between pods from trees containing different isolates of virus and between pods from infected and uninfected trees. These differences were apparent from the earliest measurements. Lesion sizes in pods from trees with Severe New Juaben and Bisa isolates were significantly greater than those in the control series, and lower than the control in pods from trees of the other pair showing Mild New Juaben and Kpeve symptoms.

Müller & Munro (*Ann. appl. Biol.*, **38,** 765, 1951) found that the behaviour of *Phytophthora infestans* on potato was modified by different strains of the same virus. However, they recorded that growth of *P. infestans* was retarded in inverse proportion to the severity of virus infection whereas in the case of *P. palmivora*, it appeared that the fungus lesions developed more rapidly on pods infected with the more severe virus isolates than on ones infected with the Mild New Juaben isolate.

LEAF INFECTION (A. L. Wharton)

Phytophthora palmivora has been found attacking leaves of mature trees and young shoots in Ghana. The fungus was isolated from the tissues, identified in sections and successfully inoculated into undamaged seedlings using zoospore suspensions. On flush leaves the symptoms are characterised by necrosis spreading rapidly down the main veins. Spread through the lamina is more restricted but the necrosis here is preceded by a marked clearing. It is considered that the symptoms are so similar to the common tip necrosis of flush leaves on mature cocoa in the British Cameroons that the disorder there is almost certainly caused by *Phytophthora* attack, a possibility suggested previously (*Rep. W. Afr. Cocoa Res. Inst.*, 1957–58, p. 29).

MINOR FUNGAL DISEASES OF COCOA (P. D. Turner)

In an investigation of minor fungal disease of cocoa isolations were made from fruits at all stages of development. Diseased cherelles and immature pods yielded only species of *Fusarium*, but a large number of other species of fungi were isolated from diseased ripe pods. These included *Aspergillus niger* van Tiegh., *Botryodiplodia theobromae* Pat., *Cephalosporium acremonium* Corda, *C. humicola* Oudem., *Cephalosporium* spp., *Curvularia* sp. *Gliocladium penicilloides* Corda, *G. roseum* (Link)

Thom, *Helminthosporium* sp., *Hormodendrum cladosporioides* (Fres.) Sacc., *Mortierella* sp., *Mucor* spp., *Nigrospora sphaerica* (Sacc.) Mason, *Penicillium* spp., *Pestalotiopsis* spp., *Phycomyces* sp., *Rhizopus nodosus* Namyslowski, *Trachysphaera fructigena* Tab. & Bunt., and *Verticillium* sp. The majority of these fungi appear to be saprophytic or only weakly parasitic. Inoculation tests with the isolates of *Trachysphaera*, *Botryodiplodia* and *Pestalotiopsis* showed that these fungi do not infect unwounded pods, and that greater development occurs in ripe than in unripe fruits.

MEALYBUG STUDIES

JOINT W.A.C.R.I.-DIVISION OF AGRICULTURE MEALYBUG CONTROL TRIALS

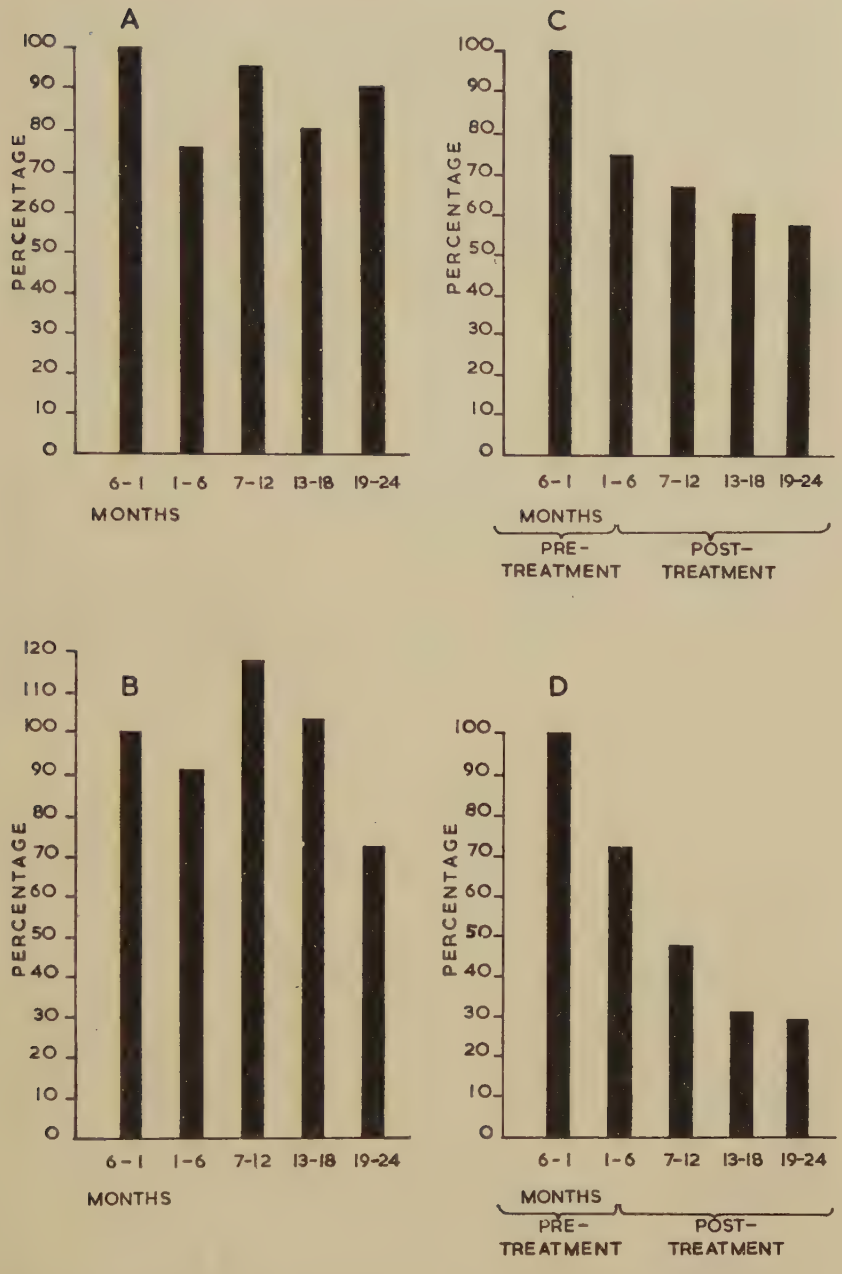
(P. F. Entwistle)

The experiments at Oyoko on the control of swollen shoot disease vectors through the destruction of the attendant ants by the use of dieldrin have been continued (see *Rep. W. Afr. Cocoa Res. Inst.*, 1957–58, p. 31). During the past year another double application of dieldrin has been made to the 200-acre treated area. The treatment differed slightly from the first in that only the tree trunks were sprayed, with 1 lb. toxicant in 20 gallons of water per acre. The two applications were made from 16th June to 9th July 1958 and 16th August to 8th September 1958 respectively, the interval between applications being shorter than that in the first year.

Populations of crematogasterine ants fell to lower levels than those recorded after the initial double treatment with dieldrin. Except in a few small farms lying rather close to the edge of the treatment area, or near food farms, populations of *Pseudococcus njalensis* Laing, estimated by counts made on trees to hand height, fell to zero during the second month after treatment. This species was virtually absent until the end of March 1959 with minor infestations on only a small number of trees. The high numbers counted in some farms, which have considerable weight in graphically presented data, may possibly be due to incomplete spraying. During the second treatment certain small food farms enclosed in the treated area could not be sprayed, owing to damage to growing crops of maize and cassava. These remained as internal foci for reinfestation by both ants and mealybugs.

All trees were inspected for virus infection each month. Both the control and treated areas were divided into equal halves—in one half only visibly-infected trees were removed, while in the other half visibly-infected trees and trees in physical contact with them were removed.

Virus incidence under the various treatments is shown in Figure 2.



N.B. VIRUS INCIDENCE AS PERCENTAGE OF PRE-TREATMENT INCIDENCE

FIGURE 2. Histograms to illustrate changes in virus incidence in the Oyoko swollen shoot control experiments: A—control, visibly-infected trees felled; B—control, visibly-infected and contact-trees felled; C—treated, visibly-infected trees felled; D—treated, visibly-infected and contact-trees felled.

The removal of trees in physical contact with those showing active virus symptoms is clearly more effective than the removal of infected trees alone. In areas where contact-trees have been removed the number of virus-infected trees removed each month has been reduced to half that where visibly infected trees only have been removed (29 per cent. of pre-treatment levels as compared with 58 per cent.).

It is not intended that further dieldrin treatments should be made, and the vector populations will be allowed to recover. Cutting-out will be continued as before in order to see if it is possible to contain the virus close to the lowest level obtained following vector control.

The absolute lowest level to which virus incidence can be reduced by the present system of vector control has not been established. As mentioned previously (*Rep. W. Afr. Cocoa Res. Inst.*, 1957–58, p. 33), certain species of mealybugs are not susceptible to the treatment and remain as a low-level residual population, after the elimination of *Ps. njalensis*, and will always spread some virus. Obviously there must come a time when there is so little virus spread that it is more economic to rely on the cutting-out of trees alone than to apply more insecticide. The validity of this naturally relies upon the sustained containing effect of cutting-out upon reduced levels of virus infestation, upon which data should become available during the next two years, whilst the point at which such a principle becomes operative is a function of the cost of vector control measures.

CAPSID STUDIES

JOINT W.A.C.R.I.-DIVISION OF AGRICULTURE CAPSID CONTROL TRIALS

(C. G. Johnson)

After two full seasons field trials in the Eastern Region (with both small scale and large scale units) using Endrin, Dieldrin, Aldrin, Gammalin and Malathion, a sufficient mass of data has been accumulated and the trials discontinued. Dieldrin is proved unsuitable for use against capsids because of the danger of subsequent increases in *Marmara* damage. Malathion gave unsatisfactory capsid control at economic dosages. In Ashanti the trials with Endrin, Aldrin and Gammalin at dosages approximately equal in cost per acre (see *Quart. Rep. W. Afr. Cocoa Res. Inst.*, No. 50) will continue.

With both series of trials the same general picture appears, as with earlier preliminary trials in 1956 (*Rep. W. Afr. Cocoa Res. Inst.*, 1956–57). Comparing similar dosages of toxicant Endrin is outstandingly effective, Gammalin and Aldrin being next in order of efficiency. In all trials Aldrin is consistently less effective than Gammalin but the differences between the two are very small—of

the order of 3 per cent. difference in the numbers of capsid-damaged trees. Aldrin has therefore been considered suitable for capsid control in Ghana, provided that on retreatment the chemical is applied at the rate of 2 oz. per acre. A full account of this work will be published elsewhere.

LABORATORY ASSESSMENT OF INSECTICIDES (K. B. Armstrong)

Many problems connected with the action of insecticides in the field, e.g. persistence, the absorption of insecticides by foliage and the possibility of a partial systemic action by the chlorinated hydrocarbons, taint, the incorporation of resins in sprays, etc., are now being studied in the laboratory in close association with work already in progress in the field.

Investigations have begun into the efficacy of various *gamma*-BHC formulations and a comparative laboratory bio-assay technique, using capsids, has been established. Capsids have been difficult to breed in the laboratory, neither 'small chamber' nor 'mass breeding' techniques were satisfactory. A colony of *Dysdercus* spp. (Pyrrhocoridae) is being established for use as assay material in these experiments. The insect is more robust and easier to breed than capsids, is susceptible to the same dosage range of *gamma*-BHC, and should provide a useful comparison.

MINOR PESTS OF COCOA

POD HUSK MINER (P. F. Entwistle)

Under natural conditions *Marmara* (Lepidoptera, Gracillariidae) appears to be held in check by at least three species of parasitic Hymenoptera, of which the adults of two have been reared. These have been identified by the Commonwealth Institute of Entomology as *Bracon* sp. (Hymenoptera, Braconidae), and *Ageniaspis* sp. (Hymenoptera, Encyrtidae). During peak population periods the rate of parasitism of *Marmara* is extremely high, being in the region of 60 per cent., the greater part of which is due to the endoparasitic encyrtid *Ageniaspis*. In addition, a further 18 per cent. have been recorded as dying from natural causes.

Such observations as have been made indicate that like other known members of the genus *Ageniaspis* this species is polyembryonic in habit: several parasite larvae are to be found in each host larva (up to twenty-four have been observed in one host) and the parasitised final stage *Marmara* larva is larger than its healthy counterpart. The parasite cocoon, which is formed internally, has been observed only in the final instar host larva.

Bracon is externally parasitic on both pre- and post-hypermetamorphic larvae of *Marmara* and prior to pupation spins a white ovoid cocoon close to the exhausted host skin within the pod-mine. It is much less important than *Ageniaspis*, and at Tafo parasitises between 2 and 3 per cent. of the peak *Marmara* population.

The third chalcidoid parasite has been noted on one occasion, but the adult stage was not obtained.

These brief data on parasitism tend to support the suggestions implied in the 1957–58 Annual Report that an upsurge in *Marmara* populations subsequent to the application of heavy doses of a persistent insecticide is due to an upset of the natural biological balance through a differential kill of host and parasite. Where there is a low natural rate of parasitism such an effect would be small, but there is a naturally strong parasite restraint upon *Marmara* which leads to a consequently bigger response to such insecticidal treatment.

CERAMBYCIDAE (P. F. Entwistle)

During the past year work has been in progress on the taxonomic aspects of those species of *Tragocephala* attacking cocoa in West Africa. Over thirty-six varieties of the *Tragocephala nobilis* F. have been described in the literature: it is apparent that those attacking cocoa, and some of their allies, warrant species status and this has been conferred upon the described varieties *T. nobilis* var. *castnia* Thoms., *T. nobilis* var. *gorilla* Thoms. *T. nobilis* var. *maynei* Gah., *T. nobilis* var. *bassamensis* Thoms. and *T. nobilis* var. *chloris* Chev. In addition it has been necessary to separate two new species from *T. bassamensis* (*T. trifasciata* sp. n. and *T. chloriformis* sp. n.).

In Ghana the principal species attacking cocoa is *T. castnia* and no authentic records of *T. gorilla*, with which it has been much confused in the past, are known. The confusion has largely arisen out of the variability of elytral colour pattern in *T. castnia*, one extreme being superficially similar to *T. gorilla*, a species showing very little variation (Fig. 3). There are, however, several distinct points of difference which may be relied upon to separate any form of *T. castnia* from *T. gorilla*, and these are summarised in Table 4.

T. gorilla has, however, been recorded from Volta Region (Peki, P. F. Entwistle, 1959) and appears to be the principal species on cocoa in Nigeria. In Ghana *T. castnia* is widely distributed throughout the cocoa-growing regions, reaching from Dormaa-Ahenkro in the north-west to Tarkwa in the south and Tafo in the south-east; authentic specimens have been seen from the Ivory Coast.

T. nobilis has also been recorded on cocoa at Tafo but has not been noted outside this area so far, though again specimens have been seen

TABLE 4

Distinguishing features of TRAGOCEPHALA CASTNIA *and* T. GORILLA

T. castnia	*T. gorilla*
Pubescence on ventral side of first antennal segment is glaucous-green.	Pubescence on ventral side of first antennal segment is grey.
Black triangle on vertex of male generally reaches the eye and antennal socket.	Black triangle on vertex of male never reaches the eye or antennal socket.
Elytral pattern very variable; basal and median orange bars generally separate, but where joined the resultant black median bar distinctly emarginate laterally.	Elytral pattern very constant; basal and median bars always joined and the black central bar never more than slightly emarginate laterally.
Setae at tip of parameres of male as long, or nearly so, as the paramere itself.	Setae at tip of parameres of male never more than two-thirds length of paramere.

from the Ivory Coast, and one from the Belgian Congo was also noted, though this was not definitely associated with cocoa. In the past this species has been persistently confused with *T. chloris* which is not definitely known to attack cocoa. The two may be distinguished by the yellow basal elytral band being always divided into two in *T. nobilis*, which is also the more robust insect, whilst the band is continuous laterally in *T. chloris* (see Fig. 3). The results of this work will be published in greater detail elsewhere.

Parasites of Tragocephala

A new species of Tachinidae (Dexiinae), frequently recorded as an internal parasite of the larval stages of *T. nobilis* and particularly *T. castnia* at Tafo has been described by R. G. Fennah, of the Commonwealth Institute of Entomology, as *Billaea vanemdeni* (Fennah, *Ann. Mag. nat. Hist.*, ser. 13, i, p. 682, 1958). Type material is in the British Museum (holotype male).

A chalcidoid egg parasite of *T. castnia* has been recently noticed at Tafo and is very similar to specimens bred from eggs received from Mayumbe, Belgian Congo. The host to the latter specimens is probably either *T. maynei* or *T. guerini*. Determination of these two parasites is awaited.

Biology of Tragocephala

A simple laboratory breeding technique, which has been successful with *T. nobilis*, *T. castnia* and *T. gorilla*, has been developed. Adult insects, enclosed in lamp-glass cages, are fed on fresh pieces of green cocoa chupon. Mating occurs freely within the cages, oviposition

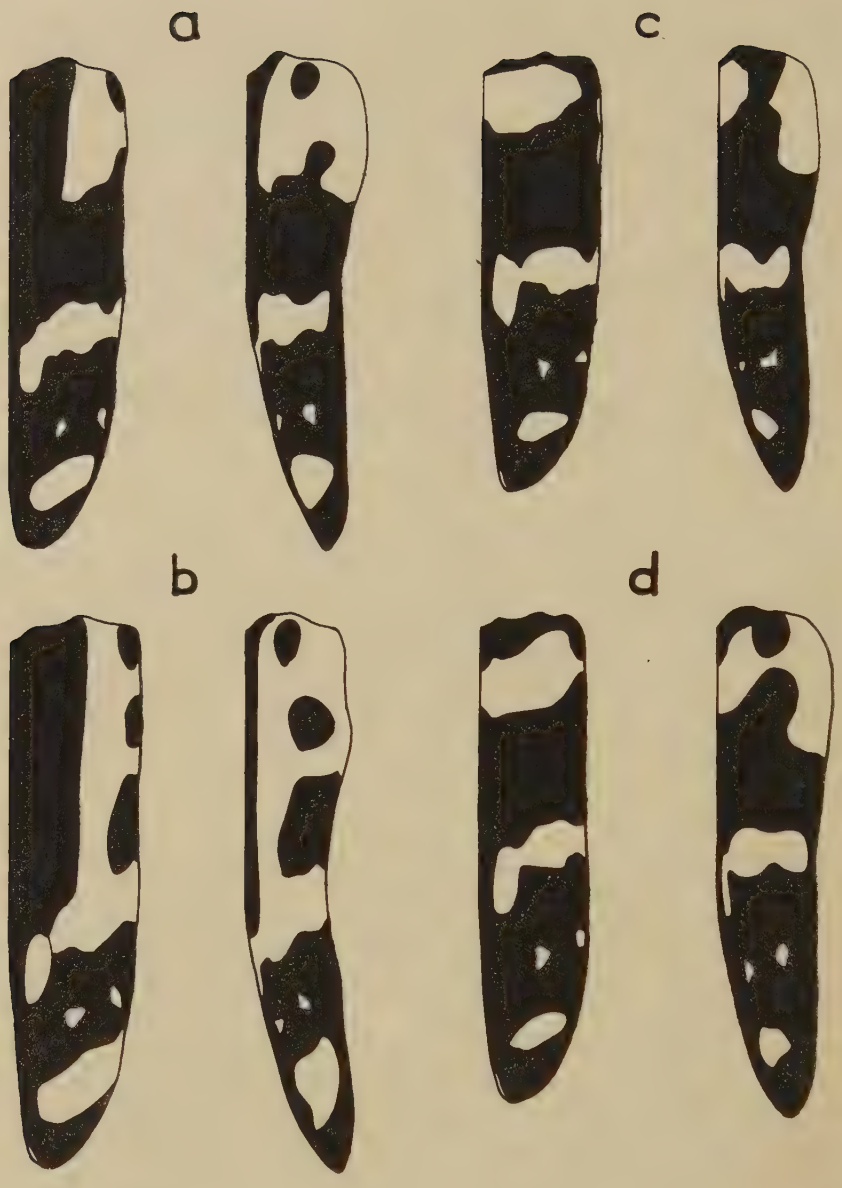


FIGURE 3. Dorsal and lateral views of elytra of: (*a*) *Tragocephala castnia* Thoms.; (*b*) *T. gorilla* Thoms.; (*c*) *T. nobilis* F.; (*d*) *T. chloris* Chev.

taking place on the food material. Short lengths of chupon containing eggs are retained in closed petri dishes till eclosion of the first instar larvae. These, on emergence, are placed in artificial burrows made in partially dried green wood, wilted and less sappy tissue being

necessary for the survival of young larvae. Subsequently they are transferred to thicker lengths of slightly older fresh wood, this being renewed as soon as the larva has burrowed down its length. On pupation they are removed to hollowed stems of dry wood to await emergence of the perfect insect.

Data are available for the *in vitro* life cycle of *T. castnia* (see Table 5), but comparable field records are not yet complete.

TABLE 5

Life cycle of T. CASTNIA

	Range (days)	*Mean (days)*
Egg incubation period	9–13	11.8
Larval period	70–125	104.5
Pupal period	19–28	20.9
Adult immaturity period	—	♂20 ♀14
Time from mating to oviposition ..	2–30	12.0
Total length of adult life	10–207	102.2
Average life-cycle, egg to egg	—	163.4

After emergence from the pupal skin the adult insect normally rests within the pupal cell for a period varying from 8 to 18 days (mean of 11.7) before emergence. In captivity feeding does not generally start till one or two days after leaving the wood.

SHOT-HOLE BORERS (P. F. Entwistle)

As a result of identifications made by the Commonwealth Institute of Entomology, shot-hole borer damage to seedling cocoa in Sierra Leone has been found to be principally associated with *Xyleborus morstatti* Haged (see *Rep. W. Afr. Cocoa Res. Inst.*, 1957–58, p. 44). Of the ninety-nine adult insects, received either in spirit collections or removed from samples of chupon tissue, ninety proved to be *X. morstatti*, four were *Hypothenemus mozambiquensis* Egg., four *H.* sp. ? *pusillus* Egg., and one an unidentified species. Attack by *X. morstatti* on seedlings has been noted at Tafo, but is of little importance.

The species listed in Table 6 have been recorded on cocoa in Ghana during the past year, all following prior damage to the attacked tree (either by root fungus or lightning strike).

Throughout West Africa the principal species attacking cocoa seems to be *X. morstatti*, it is probable that entirely healthy plants are not susceptible. Primary shot-hole borer attack seems to be less common in Ghana than in other West African cocoa producing countries. Secondary shot-hole borer damage has often been confused with other causes of death or injury.

Table 6

Borers recorded on cocoa in Ghana

SCOLYTIDAE

Xyleborus mascarensis Eichh.
X. camerunus Hgd.
X. urichi Samp.
X. collarti Egg.
Hypothenemus ater Egg.
H. sp. ? *pusillus* Egg.
Stephanoderes sp.

PLATYPODIDAE

Doliopygus V-grandis Samp.
(Others still await identification.)

LEPIDOPTERA (M. R. Smith)

The removal of shade trees from mature cocoa has given substantial increases in yield (see p. 51) but must be expected to cause changes in the insect populations inhabiting the crop. Different species have different light requirements, and insects which under shade are rare or unknown could become serious pests. Increased light may also affect the physiology of the cocoa tree, and indirectly cause changes in the insect population.

Investigations into the differences in populations of lepidoptera in shaded and unshaded cocoa have started with a preliminary survey of lepidoptera on cocoa. The use of insecticides may also considerably modify insect populations and this is also being studied. Larvae are being collected in the field, and bred through to the adult stage. A collection of parasites is being made at the same time. Approximately 100 different species of lepidoptera have now been recorded on cocoa at W.A.C.R.I., though many of these occur very infrequently. The commonest species at W.A.C.R.I. between September 1958 and April 1959 were *Earias biplaga* Wlk. and, to a lesser extent, *Anomis leona* Schauss.

Adults which emerge in captivity often refuse to mate or lay eggs. To obtain details of life histories, light traps are used to capture fertile females, which will often oviposit in captivity.

POD FUMIGATION (K. B. Armstrong)

Pods sent out of Ghana for use as seed are at present dipped in an ethanolic solution of mercuric chloride (approx. 0.4 per cent.) to kill fungus spores. It has been found that this treatment is not adequate to kill mealybugs harbouring in the pods, particularly those which colonise *Characoma* mines. Attempts have therefore been made to develop a method for fumigating pods, with the following results.

Cocoa sacks, approximately 5 cu. ft. in volume, were provided

with a polythene lining and each filled with approximately 170 pods. In each sack three pods infested with mealybugs (placed beforehand in artificial mines made by a cork-borer) were placed in the bottom, middle and top sections of the sack. The sacks were then tied and sealed after a wad of mutton cloth saturated with fumigant had been dropped into the top of the sack. The fumigant used was a 50/50 mixture of ethylene dichloride and carbon tetrachloride with a range of 1 oz. to 9 oz. per sack. The pods and fumigant were left for forty-eight hours in the sealed sacks, stacked in an open shed.

The results were somewhat variable owing to tears developing in the polythene liners, but briefly, it may be said that 100 per cent. kill was obtained with the amounts of fumigant above per sack, while there was 26 per cent. mortality in the untreated controls. Germination tests showed no ill-effects, from fumigation at the 6 oz. fumigant or less used per sack. The method is very promising, but improved liners are necessary.

ESTABLISHMENT AND MAINTENANCE TRIALS

(R. W. Smith)

AMELONADO SPACING TRIAL

The yields from all treatments of the Amelonado Spacing Trial, which was planted eleven years ago, have again increased. The results for the 1957–58 and 1958–59 seasons are given in Table 7.

TABLE 7

Yields from the Amelonado Spacing Trial for the 1957–58 and 1958–59 crops and the total crop

Spacing	15′×15′	12′×12′	10′×10′	7½′×7½′	7½′×6′	6′×6′	5′×5′	4′×4′
Equivalent density (trees per acre)	193	302	435	774	968	1,210	1,742	2,722
Pods per tree								
1957–58*	55.3	39.8	33.5	21.3	14.0	10.1	8.2	4.6
1958–59	91.1	62.4	53.1	32.3	22.2	16.4	13.4	8.1
Total	182.6	126.4	104.4	69.8	47.0	34.3	27.5	20.5
Dry cocoa per acre (lb.)†								
1957–58*	890	1,005	1,215	1,375	1,200	1,015	1,190	1,035
1958–59	1,465	1,570	1,925	2,080	1,790	1,650	1,905	1,835
Total	2,940	3,180	3,860	4,500	3,800	3,465	4,070	3,585

* Because better estimates, both for the conversion factor from number of pods to lb. of dry cocoa and for allowances for missing trees, have been used, these values differ from those previously published in the W.A.C.R.I. Annual Reports.

† Estimated from sample fermentations.

The spacing $7\frac{1}{2}$ ft. $\times$ $7\frac{1}{2}$ ft. continues to give the highest yield per acre. The exceptionally high yields during the past two seasons suggest that the cocoa is now approaching full bearing. The shade was completely removed during 1958–59 and this has probably contributed to the high yield (p. 54).

The main effect of increasing spacings on the cocoa, is to increase the yield of the individual trees. However, yield per acre is an interaction of the number of trees per acre and the yield per tree. As the relationship between yield per tree and tree density is of a hyperbolic nature there is a tendency for a decrease in tree population to be balanced by a corresponding increase in yield per tree. However, the peak in yield per acre at the 774 trees per acre density ($7\frac{1}{2}$ ft. $\times$ $7\frac{1}{2}$ ft. spacing) has proved consistently significantly better than the other treatments. At this spacing, it is likely that maximum use is being made of the soil space without there being undue competition between the trees, and as the canopy is completely closed, the cocoa stand is in an optimum condition.

A routine fertiliser dressing is to be applied during 1959–60 season.

AMAZON SPACING AND PRUNING TRIAL

No conclusions can yet be drawn from this trial. As in the Amelonado trial reported above, yield per tree increases with wider spacings. Here 10 ft. $\times$ 10 ft. spacing has given the best yields per acre, over the last two seasons. No effect of the pruning treatment has been apparent to date.

PILOT IRRIGATION TRIAL

The trial consists of two replications of three different water regimes. The records are for plots of thirty trees surrounded by one guard row. Treatments were started on 15th December 1958 and the results given cover the period up to 15th March 1959. During this period there was little rain (total 7.08 in.).

At the beginning of the trial there was little difference among the trees subjected to the various treatments. Table 8 shows the differences after three months' treatment.

Records of flushing were taken weekly. Flushing on the trees in the watered plots was greater than on those receiving no added water. The mean percentage of trees in flush in each week over the experimental period was, treatment A, 32 per cent., treatment B, 42 per cent., and treatment C, 45.5 per cent.

In all the plots the first flush peak was reached on 8th January. Following this the watered plots reached a second flush peak in the middle of February, some two weeks earlier than the Controls. The

Controls reached their second flush peak on the 21st February following the rains of the 10th and 15th February.

TABLE 8

The effect of irrigation from 15th December 1958–March 1959 on the growth of young cocoa

Treatment	*A*	*B*	*C*
Mean increase in height (in.)	2.16	5.33	6.09
Mean diameter 6 in. above ground (in.) ..	0.43	0.48	0.48
Mean number of leaves per tree	9.1	13.1	13.2
Mean leaf length (in.)	9.76	9.79	10.73

Treatments *A*=Control—No water added.
B=Soil not permitted to dry out below 13% moisture.
C=Soil not permitted to dry out below 18% moisture.
Field capacity=22% and wilting point= 5%.

PLANT BREEDING AND SELECTION

PROGENY AND INTRODUCTIONS TRIALS (D. R. Glendinning)

Yields in all Botany plots have again risen. Table 9 shows the totals of pods harvested from the experimental areas of the main trials and plantings in the last three seasons.

TABLE 9

Pods harvested from the main Botany Plots

	Year Planted	*Experimental Area*	1956–57	1957–58	1958–59
Trinidad introductions ..	1945	12.3 acres	55,000	92,000	122,500
First clonal trial	1947	4.4 acres	24,000	37,000	58,000
Second clonal trial ..	1948 (Sept.)	2.8 acres	12,000	24,000	30,000
Eighth PTA	1952	1.9 acres	6,000	10,500	19,500
Ninth PTA	1954	5.2 acres	3,000	44,000	68,000
Totals		26.6 acres	100,000	207,500	298,000

In the case of the 8th and 9th Progeny Trials this increase is primarily attributable to increasing age, but in the other plots, which have been in bearing for some time, it is probably due mainly to shade reduction and fertiliser application. The 8th P.T.A. has also received a fertiliser dressing, but not the 9th P.T.A. where varieties are being assessed under conditions as nearly equivalent to those normally used by the farmer as is consistent with accurate experimentation.

A few of the better yields are recorded in Table 10.

TABLE 10

Performance of some selections: 1958–59

	Spacing	*Age from planting out (yrs.)*	*Estimated yield dry cocoa (lb./acre)** *Potential†*	*Net*
Introductions				
Trinidad Introductions Area	14′×14′			
T11		14	2,680	2,490
T6		14	2,200	2,140
T60		14	1,940	1,660
Clones				
1st clonal trial	10′×10′			
A12		12	1,910	1,630
A36		12	1,835	1,610
A46		12	1,780	1,500
ACU85		12	1,800	1,700
K5		12	1,680	1,600
S27		12	1,740	1,600
2nd clonal trial	8′× 8′			
R15		10½	2,125	1,690
D70		10½	1,830	1,790
W41		10½	1,730	1,510
ICS7		10½	1,610	1,510
New Crosses				
8th progeny trial	8′ × 8′			
WAE5		7	1,660	1,515
WBE3		7	1,515	1,240
9th progeny trial	10′×10′			
WEB1		5	1,540	1,090
WAE11		5	1,370	1,130

* Based on an assumed conversion rate of 40% on fermenting and drying the wet beans.

† 'Potential' yield is based on the assumption that all pods harvested are usable. 'Net' yields are the amounts remaining after deduction of all diseased and damaged pods. As some cocoa is recoverable from damaged pods the actual yield will lie between these values. Previous reports have given only the potential yields.

The new hybrids, especially those in the 9th Progeny Trial, continue to grow with outstanding vigour. This trial, planted in the field in 1954 from seed sown in 1953, gave a measurable yield in the 1956–57 season (one variety exceeding 100 lb. per acre of dry cocoa), substantial yields in the 1957–58 season (two varieties exceeding 1,000 lb. per acre potential yield), and has given still more in 1958–59 (see Tables 9 and 10). Incidence of pod disease and rodent damage has been heavy, WEB2 being the worst affected with 44 per cent. incidence (including 13 per cent. black pod). Much useable cocoa is of course recoverable from damaged pods. Stem cankers believed to be caused by *Phytophthora* have been found on WEB2.

In the 'Series I' Trials, seventeen of which have been planted in collaboration with the Divisions of Agriculture in Ghana and Nigeria

since 1953, both yield data and observations on stem diameter continue to show the superiority of the Amazon types over the local selections.

The new hybrids have been planted in thirteen 'Series II' Trials in Ghana and Nigeria since 1956, and some of these are already coming into bearing. Growth rates in general are very high.

A trial including both Series I and II varieties is about to be planted in Sierra Leone.

A trial to compare the F1, F2, and F3 generations of an Amazon type (T82) has been planted. The F1 generation was produced by hand-pollination between the clones of the parents of the original pod T82. (These clones had been obtained from Trinidad.) The F2 pods were open-pollinated, and were taken one from each of a number of F1 trees. The F3 pods, also open-pollinated, were obtained from a number of Division of Agriculture plots.

It is not yet possible to assess whether the differences in vigour that are apparent in the field are inherent, or whether they only reflect differential treatment received by the seedlings of the various generations in the nursery. The F1, however, appears to be superior.

VARIABILITY OF CERTAIN AMAZON INTRODUCTIONS (M. Wessel)

The weight of cocoa and number of beans per pod has been studied for a number of individual Nanay and Parinari trees. There is considerable variation from tree to tree which is presumed to be primarily genetic, though no clear-cut segregation ratios were detected. The information will be of immediate use in selection of trees for use in the breeding progamme.

CLONAL SEED-GARDENS (D. R. Glendinning)

It is planned to mass-produce seed of the new hybrids by inter-planting clones of the parent trees and allowing them to inter-pollinate. Cuttings from the trees have been passed to the Divisions of Agriculture in Ghana and Nigeria, and planting of seed-gardens has started. This does not constitute a release of these varieties by W.A.C.R.I., but is rather a means of reducing the interval between formal approval being given for the issue of a particular hybrid and seed reaching the farmers in quantity.

The possibility that pollinating insects may introduce contaminant pollen from outside the seed garden must be recognised. Knowledge of the distance over which pollen is normally carried is very scanty. Evidence from the 2nd Albino Plot at W.A.C.R.I. suggests that about

10 per cent. of all pollination takes place over distances greater than 50 ft. (about 40 per cent. of pollination at the centre of a plot of 13 trees × 13 being from outside the plot (*Rep. W. Afr. Cocoa Res. Inst.*, 1957–58). In a 5-acre block of a self-incompatible clone at Bunso substantial numbers of pods are set at the centre of the plot, showing that some pollen must be carried over considerable distances.

When both parents of a hybrid are self-incompatible they will be inter-planted in equal numbers and pods harvested for seed from both, and it is hoped that the preponderance of 'selected' pollen will, for all practical purposes, pre-empt contaminant pollen. However, when only one of the parents of the hybrid is self-incompatible, the pollen-parent will for reasons of economy be planted at a lower density, and accidental pollination may then be more important. Where the proper pollen parent is a selected Amelonado, the consequences would probably not be very serious if contaminant pollen were mainly local Amelonado, as the genetic differences between the various Amelonado selections are believed to be small.

Where the intended pollen parent is distinct from Amelonado, however, contamination must as far as possible be avoided. This can be done in three ways, by planting the seed-gardens in complete isolation from other cocoa (e.g. in forest reserves), by planting large gardens of 10 acres or more and discarding the produce of the outer eight rows of trees (which, for convenience and efficiency, could be planted with the pollinator clone), or by producing the pods by hand-pollination. The last method would be the most completely reliable, but would also be slightly more expensive. Hand pollinating would probably cost about sixpence per pod, and add perhaps six shillings to the cost of establishing an acre of cocoa.

PHYSIOLOGY OF FRUITING

(R. G. Hurd)

CHERELLE WILT IN THE TRINIDAD INTRODUCTIONS

A further year's results again show that yield and percentage wilt are not related, a correlation coefficient of −0.4 was obtained with this year's data. Therefore, there is little point in selecting cocoa for low wilting performance.

Over the last three years percentage wilt fluctuated appreciably within and between selections. A few types had consistently low wilt (T12 and T61) and a few had relatively high wilting values every year.

SOIL FERTILITY, SHADE, AND FERTILISER REQUIREMENTS

NUTRIENT CULTURE (R. G. Hurd)

Growth of cocoa in different nutrient culture solutions

An experiment outlined previously (*Quart. Rep. W. Afr. Cocoa Res. Inst.*, No. 49) has now been completed. Plants were grown in six different water culture solutions each with either K, Mg, Ca, N, P or S as the dominant ion. All the solutions contained only these elements together with a complete minor element mixture. It was intended to investigate the method of systematic variations in which Homes (*Publ. I.N.E.A.C.*, **58,** 128, 1953) claims that given the dry weight of plants grown in these solutions it is possible to predict the nutrient solution which will give optimal growth.

The fresh weight and final dry weight of each treatment is given in Table 11. With such a high variability only the difference between the Ca treatment and K, N and P achieves significance.

TABLE 11

Fresh weight and final dry weight of cocoa in water cultures of different nutrient composition (Homes type)

Dominant ion / *Time in culture*	*K*	*Ca*	*Mg*	*N*	*P*	*S*
			Fresh weights (g.)			
0 months	40.5	40.1	38.9	36.0	40.3	37.4
3 ,,	88.3	121	98.6	58.7	94.0	96.7
6 ,,	242	333	293	205	263	262
9 ,,	420	625	501	390	459	480
11 ,,	644	742	576	443	514	581
			Dry weights (g.)			
11 ,,	165±30	234±31	184±25	134±29	155±23	180±25

Cocoa transplated after 5 months in soil in baskets. Mean of 6-10 plants.

The optimal solution (according to Homes) is calculated for cations from the ratio of their yields in the solutions in which they are the dominant cation. A similar ratio for the anions is calculated. The absolute amounts required can be obtained by subsequent experiment but can be expected to add up to a total salt concentration of the order 0.01N.

The formula which can be devised in this way from the results is as follows:

K	28%	N	29%
Ca	40%	P	33%
Mg	32%	S	38%

A conventional solution (Hewitt, *Sand and Water Culture Methods* 1952, p. 189) has the following ratio:

K	26%	N	59%
Ca	51%	P	23.5%
Mg	23%	S	17.5%

Owing to the variability within a treatment only outstanding differences can be commented on and these concern the anion proportionality. The nitrogen content of the 'Homes' formula is half that of the 'Hewitt' formula with the result that the other two ions, particularly sulphate, are much higher. Even if the mean yield for the N and S solutions was in error by a total of two standard errors this could only bring the yields to approximately the same value and the ratio of N to S to approximately one. Homes does not quote the concentrations he used but only the amount supplied to the plants. Homes optimal solution is as follows for cocoa:

K	21%	N	37%
Ca	35%	P	34%
Mg	44%	S	29%

This differs appreciably from the results obtained here especially with regard to the N and S content. There are several differences in technique (particularly with regard to the presence of 'inactive' ions such as HCO_3^- in Homes' solutions) so it is of little value to speculate on the causes. It is hoped to grow cocoa in water culture in all three of the solutions quoted above to see which is the best.

By growing cocoa in water rather than sand culture it was possible to weigh the plants at intervals and to calculate approximate dry weights and hence relative growth rates (RGR). The final fresh/dry weight ratio was calculated for each plant and was found in an analysis of variance to vary significantly between treatments (Table 12).

The RGR over three 3-monthly intervals allowing for these differences is recorded below for each treatment (Table 13).

Table 12

Fresh weight/dry weight ratio of six month old cocoa in water culture

Dominant ion	*Fresh weight/ dry weight ratio*
K	3.90±0.25
Ca	3.23±0.10
Mg	3.13±0.07
N	3.52±0.16
P	3.34±0.14
S	3.26±0.10

Significant difference at 5% level.

Table 13

Relative growth rates of cocoa grown in different nutrient solutions in water culture

Time in culture \ *Dominant ion*	*K*	*Ca*	*Mg*	*N*	*P*	*S*
0–3 months	0.061 ±0.009	0.084 ±0.007	0.081 ±0.009	0.052 ±0.01	0.074 ±0.009	0.079 ±0.008
3–6 months	0.077	0.078	0.069	0.079	0.077	0.069
6–9 months	0.042	0.049	0.044	0.052	0.040	—

It will be seen that by far the greatest influence of the different solutions took place in the first three-month period, after this the RGR was relatively constant within each three-monthly period. It appears that the plants have taken some time to adapt themselves to the nutrient culture conditions but from three to six months they are all growing at approximately the same rate of about 0.075g/g/week which is slightly higher than that obtained in the field under very approximately the same degree of shade (0.066g/g/week, see 'Growth analysis of cocoa up to bearing' in this report). It is possible that

nutrient supply was becoming limiting between the sixth and ninth month in culture as the RGR dropped in all cases from about 0.075 to 0.045g/g/week.

This apparent adaptation to the nutrient solution is of considerable significance when considering the value of this method of determining the optimal nutrient solution. Homes states that ideally a fresh determination must be carried out at each phase of growth and with each type of cocoa but it seems likely that the result would depend entirely on the composition of the previous nutrient medium in which the plant had been growing.

The leaf area measurements were too variable to obtain very accurate estimates of net assimilation rate (NAR) in the different solutions. Over a two-week period when the plants had been in the nutrient solution for four months the NAR varied from 0.065 to 0.142 for individual plants and the overall mean for all the treatments was 0.098g/sq.dm/week. This is slightly higher than that obtained with young cocoa in the field (0.056–0.08).

In general it has been noted that the leaves stay on the plant longer than is usually observed in the field; several leaves which were first recorded as being longer than 2 cm. over nine months ago still appear to be healthy. It is impossible to keep the roots free from fungal infection. At fortnightly intervals the roots were dipped into a 0.1 per cent. chloramine T solution in an attempt to combat this following a suggestion that this had been effective at East Malling research station. It seems likely that the great variability noted in the growth rate of replicates in water culture is due to this infection of the rooting system. Plants grown in sand culture are more uniform. The rooting system in water culture is quite different from that obtained in the field; lateral roots emerge at all levels of the tap root and branch extensively. Some die and it is not infrequent for one of the laterals to produce the majority of the roots which after about a year's growth have filled the whole 5-litre pot with a loose network of relatively unbranched small roots.

It seems that for most purposes sand cultures are to be preferred to water cultures although had they been used in this experiment the RGR could not have been calculated at intervals and the 'adaptation' described above would not have been revealed.

Growth analysis of cocoa up to the age of bearing (3 years)

A field experiment first described in *Rep. W. Afr. Cocoa Res. Inst.*, 1955–56, p. 65, has now been completed. Growth of seedlings in a sandy loam (Koforidua series) was compared with that in a sandy poorly drained soil (Akwadum series).

Originally the experiment was planted with seed from local hybrids of the 2nd P.T.A., but within six months of planting in the poor soil many of the seedlings had died. This area was replanted one year later with eight-month-old Amazon cocoa which was considered to be more able to withstand the poor soil conditions. Hence the age and variety of the plants on the poor soil differed from those in the good soil. The results are given in Table 14.

The RGR of the two series of plants has followed a similar course despite these differences. Although there are wide fluctuations from month to month which have already been discussed (*Rep. W. Afr. Cocoa Res. Inst.*, 1956–57, p. 57) there is a distinct trend in the first eighteen months towards a RGR of 0.094g/g/day in both groups of plants. The only exceptional period was the dry season six months after the beans were sown when the RGR of the seedlings in the poor soil dropped considerably.

After eighteen months the RGR of plants in both soils changed. In the good soil it dropped to 0.044 and in the poor soil 0.036g/g/day. This represents an appreciable difference and together with the six-month age lag of the plants in the poor soil mainly accounts for the considerable differences in the growth parameters recorded in Table 14.

Calculations have been made of the NAR over the period. Insufficient plants were available and the results are variable. By taking six-monthly means, figures varying between 0.056 and 0.08g/sq.dm/week have been obtained from the plants in the good soil. In the poor soil with fewer plants this variability was even more pronounced so that only over the first twelve months were any reasonable figures obtained. Excluding negative values obtained in January and February because of the extensive leaf fall the mean for the remaining ten months is 0.054g/sq.dm/week (over the same period in the good soil the mean was 0.062g/sq.dm/week) so that there appears to be little difference in the NAR under the two conditions.

The overall impression from this experiment is that the water relations of the plant have been the main factor determining the early growth of the plant. The poor physical quality of the soil has resulted in severe leaf loss in the dry season and the death of many plants. The waterlogged condition of the soil at certain times of the year must also affect growth especially after the plant's roots have grown down to this level. The drop in the RGR after eighteen months is interesting and may be associated with a preponderance of fan type growth, that is the majority of plants may have jorquetted by this time.

Table 14

Growth measurements of local hybrid cocoa in good (Koforidua series) and poor (Akwadum series) soil over the first three and a half years

Date	Height in (cm.)		Diameter at ground (cm.)		Total dry weight (g.)		Length of tap root		Leaf area in sq. dm.	
	Good soil	Poor soil	Good	Poor	Good	Poor	Good	Poor	Good	Poor
30.6.55	14.5	11.8	0.42	0.42	0.55	0.31	—	6.1	0.41	0.13
31.10.55	24.9	24.5	0.56	0.48	2.33	1.99	15.1	13.0	3.67	2.75
28.2.56	40.8	25.0	0.79	0.56	8.54	2.08	19.7	13.3	8.21	0.45*
29.6.56	61.1	33.9	1.05	0.66	19.4	4.37	22.7	21.6	16.2	2.54
		Replanted		*Replanted*		*Replanted*		*Replanted*		*Replanted*
30.10.56	94.2	49.3	1.71	0.84	66.0	11.2	26.8	23.8	46.7	11.7
27.2.57	124	65.5	2.38	1.31	145	31.6	30.6	32.4	82.5	19.2
28.6.57	166	79.1	3.14	1.46	304	38.9	36.1	38.1	154	26.8
30.10.57	216	116	3.96	2.31	516	110	35.4	38.0	225	76.2
27.2.58	261	139	5.25	2.80	1,161	193	42.7	36.1	296	31.1
26.6.58	277	134	5.84	3.10	1,615	279	43.8	39.0	544	115
30.10.58	302	174	6.36	3.63	2,055	357	48.6	39.8	578	148

Average of 20-30 plants (except the later recordings in poor soil in which as few as 5 plants had to be used). Beans sown on 1.6.55. Those on poor soil replaced on 10.7.56 with eight-months old Amazon.

* Extensive leaf fall in the dry season

The root systems of cocoa in a good and poor soil

The rooting systems of the cocoa plants in the good and the poor soil have been examined at intervals since they were planted three and a half years ago. The length of the tap root is approximately the same in both soils over the first three years although the plants growing in the good soil are considerably larger (Table 14). After this age the roots are growing into soil which is frequently below the water table in the poor soil, and their growth is arrested. (On 8th August 1959 the water table was 36 cm. below ground level.) The dry weights of the roots in the poor soil are lower so that the tap roots in these conditions are much thinner than those in the good soil. It should be mentioned that the routine monthly samples were extracted by removing the top soil and then pulling the plants out of the soil. The fine roots were inevitably broken off so that the root weights given represent minimal values. The rooting system in the good soil consists of a network of lateral roots branching in the top 0–12 in. of the soil and from these an occasional sinker root runs vertically to a depth approximating to that of the tap root. There are more main laterals in the poor soil and they ramify even more superficially although in both cases the laterals occupy a more shallow layer than those of temperate fruit trees. This is presumably associated with the presence of most of the soil nutrients in the top 3 in. of the soil. Fibrous roots from the laterals ramify in this layer just under the surface of the soil.

EFFECT OF MAJOR NUTRIENTS ON COCOA (R. K. Cunningham)

Trials on Amelonado cocoa

At four centres (Domiabra, Juaso, Antoakrom and Brofoyedru) responses have been obtained to applications of nitrogen and phosphate. (*Rep. W. Afr. Cocoa Res. Inst.*, 1956–57, p. 67) in the second year of the treatment.

The yields obtained in the shade and fertiliser experiment at W.A.C.R.I. (*Rep. W. Afr. Cocoa Res. Inst.*, 1957–58, pp. 58–59) for this season are given in Table 15.

TABLE 15

Shade and fertiliser yields 1958–59

Treatment	*lb. of dry cocoa/acre*
Shade/no fertiliser	958
Shade/fertiliser mixture	1,211
No shade/no fertiliser	2,348
No shade/fertiliser mixture	3,091

Trials on Amazon cocoa

At Apedwa and W.A.C.R.I. responses to phosphate have been obtained. At Bunso Plot 1006, the potash effect which has been steadily increasing became significant (P=0.05) in the fourth year of bearing. The fertiliser establishment trial on young Amazons at Plot 18C, Bunso, came into bearing during the past season and yields indicate that phosphate and potash are having beneficial effects.

EFFECT OF MICRO NUTRIENTS ON COCOA

The copper nutrition experiment (*Rep. W. Afr. Cocoa Res. Inst.*, 1957–58, p. 60) on the Old Station at W.A.C.R.I. has not revealed any responses in its first year, but is being continued. An experiment with a trace element mixture (iron, manganese, copper, zinc, boron and molybdenum) and an NPKMg basal dressing has been started at Adonkwanta using the 'subtractive' method of design.

Work has continued on the mineral deficiency area mentioned in last year's report. Pot experiments, have been carried out using the soil from this area. The pH of the soil is 7.9 and there is 1.5 per cent. free $CaCO_3$ in the top 6 in. If sulphur or aluminium sulphate is added, the pH is reduced to 7 and zinc and manganese deficiency symptoms disappear but not iron deficiency. A response to iron is only obtained when the chemical is applied as a foliar spray. These deficiency symptoms can be produced in cocoa growing on a similar soil of lower pH by over liming.

ESTABLISHMENT, SOIL EXPOSURE AND SOIL PROTECTION EXPERIMENTS

In Block A at W.A.C.R.I. in 1956, an establishment experiment was started with young Amazon cocoa on 2 acres of clear-felled land using tree cassava (*Manihot* sp.) as temporary shade. Six cover treatments were applied to the soil; bare soil, elephant grass mulch (*Pennisetum purpureum*), *Commelina nudiflora*, san hemp (*Crotalaria juncea*), indigenous grasses, and natural regeneration. In the first year, trunk diameters indicated that the mulch and the bare soil were significantly (P=0.05) better than the other treatments, a result confirmed by the yield data when the trees started to bear fruit. Fertiliser treatments were superimposed in the second year, but no significant responses were obtained.

The experiment has been used as a pilot scheme for a very large-scale, long-term shade and fertiliser experiment which will be established on approximately 35 acres of clear-felled land on Blocks K and O in the Square Mile at W.A.C.R.I. In conjunction with Plantation Management, the area has been surveyed and trees have been felled and cleared. Planting of temporary shade (tree cassava—*Manihot* sp.) and permanent shade (emeri—*Terminalia ivorensis*) has

begun and the cocoa (Amazon variety) will be planted during the June rains. Mr T. N. Hoblyn and Dr S. G. Pearce of the East Malling Research Station have given invaluable advice concerning the design of this experiment. (*See frontispiece.*)

The Amazon establishment experiment, using a Guatemala grass mulch (*Tripsacum laxum*) and an NPKMg fertiliser mixture (*Rep. W. Afr. Cocoa Res. Inst.*, 1957–58, p. 60), on a soil which had been exposed for a long time, has come into bearing in its second year. The responses to both mulch and fertiliser are significant ($P=0.05$).

A soil exposure experiment began at W.A.C.R.I. in March 1957. An old secondary forest soil was exposed by careful felling and artificial shading conditions applied immediately, *viz.* 100 per cent. shade, 50 per cent. shade and full exposure. The rate of degradation and soil moisture and temperature relationships are being followed by chemical and physical analyses.

With the Agronomy Division, an experiment has been initiated to study the protective effects of different cover crops and mulches on soil which has been exposed by clearing the forest prior to the establishment of cocoa.

LABORATORY INVESTIGATIONS

Nitrification in tropical rain-forest soils is being studied. Possible correlation between the nutrient status of cocoa soils, as assessed by chemical analysis, and the cocoa yields obtained on these soils is being investigated. These investigations are being conducted on soils within the same series, between different series and at different parts of the catena.

A NOTE ON THE POTENTIAL YIELD OF COCOA

The yield of the cocoa tree is the usual index chosen to assess the performance of the tree. If this is to be the 'yardstick', it is essential that the potential yield of the cocoa tree should be appreciated, otherwise agronomists may find that they are aiming at yield levels far below what is theoretically possible. This is particularly true in Ghana.

In a good season, Ghana can produce 250,000 tons of dry cocoa and it is estimated that there are approximately 4 million acres of surveyed cocoa. If it is assumed that 75 per cent. of this area is producing, the national average production of cocoa is approximately 190 lb. dry cocoa per acre. On the Old Station at W.A.C.R.I., 64 acres of Amelonado cocoa, growing under conditions usually found on a good farm, have yielded during the last twenty years an average of 612 lb. dry cocoa per acre (*Rep. W. Afr. Cocoa Res. Inst.*, 1957–58,

p. 15). Adams and McKelvie suggested (*Rep. Cocoa Conf., London*, 1955, pp. 22–27) that the potential yield of Amelonado may be 1,500 lb. of dry cocoa per acre. With the introduction of new varieties, the possibility of even higher yields became obvious. Estimated Amazon and hybrid yields, reported by Glendinning (*Rep. W. Afr. Cocoa Res. Inst.*, 1957–58, p. 48), vary from 800 lb. to 1,900 lb. of dry cocoa per acre. These estimations are based on a small number of trees and this method of assessing potential yield is not always reliable. Smith at W.A.C.R.I. in a 7½-acre Amelonado spacing trial under light shade (see p. 40 of this report) has, at different spacings obtained yields varying from 1,500 to 2,100 lb. dry cocoa per acre. The best treatment of the shade and manurial trial (see above) gave 3,091 lb. of dry Amelonado cocoa per acre. Amelonado cocoa planted at W.A.C.R.I. by Adams in 1953 (*Rep. W. Afr. Cocoa Res. Inst.*, 1953–54, p. 17) had its shade removed in 1955. It came into bearing in its third year although Amelonado is usually expected to bear when it is six or seven years old. When this cocoa was five years old it produced 700 lb. of dry cocoa per acre. The best treatment in the Amazon establishment experiment (see above) produced 175 lb. of dry cocoa per acre after only two years in the field. In Trinidad, Jones and Maliphant (*Trop. Agriculture, Trin.*, **35**, 272, 1958) report localised high yields from clones ranging from 1,800 to 2,500 lb. dry cocoa per acre.

These observations suggest that the potential yield of cocoa, especially Amelonado in Ghana, has been grossly underrated. It is also possible that the present accepted cocoa cultural methods employed in Ghana are as important as pests and diseases as limiting factors in cocoa production. Evidence for this is provided by the yields obtained from the shade and manurial experiment at W.A.C.R.I. This experiment is established on a soil which has been classified by Charter and Brammer (*Ghana Department of Agriculture, Division of Soil and Land-Use Survey Divisional Paper* No. 6. *Soils of Ghana*, pp. 22–23) as one of the best for cocoa in Ghana. There is no apparent virus infection, capsids and black pod are controlled and the crop is harvested regularly. Under shade without any fertiliser, this cocoa produced in the past season 958 lb. dry cocoa per acre. However, when the shade is removed and fertiliser applied, this yield, which normally would be accepted as excellent, is increased three-fold.

POT EXPERIMENTS (R. K. Cunningham and J. C. Burridge)

A pot experiment technique has been worked out which is suitable for general application to soil nutrition investigations. Five degrees

of shade in the range 0–85 per cent. were used with four major elements (N, P, K and Mg). Large nutrient responses were obtained at all shade levels. Best growth occurred under 25 per cent. shade with added nutrients and under 50 per cent. shade when no nutrients were added. A method of interpreting and applying the results in the field has been suggested. Large, healthy, vigorous seedlings were obtained in a very short time and it is possible that this technique could be used for raising seedlings in baskets in nurseries. This investigation will be more fully described elsewhere.

DESIGN OF FERTILISER FIELD EXPERIMENTS

(R. K. Cunningham and J. C. Burridge)

A comprehensive study of the yield variability of Amelonado cocoa has been carried out. Young, mature, randomly planted and uniformly planted cocoa have all been considered. Minimal requirements for field experimental design have been suggested. The more important recommendations are the use of calibration, at least twelve replicates and a minimum of sixteen trees per plot. Guard rows at least 15 ft. wide must be used between plots. This study will be reported more fully elsewhere.

COCOA PREPARATION AND QUALITY

(R. H. Kenten)

The purpose of the investigations reported below is to add to our basic knowledge of the process of fermentation and also to improve the techniques used to ferment small and large quantities of cocoa. Except where otherwise stated the quality assessments refer to those of the W.A.C.R.I. panel only and must therefore be taken as provisional.

HEAT OF FERMENTATION

When raw cocoa beans are heaped the heat produced may arise from chemical changes in the pulp, skin and cotyledon as well as from the action of micro-organisms on the pulp. To find out the importance of the various possible sources of heat, studies have been made of the rate of production of heat from whole beans and bean parts. These studies provide strong evidence that by far the most important source of heat during fermentation is that from microbial action on the pulp. It follows therefore that normal fermentation practice is dependent on chance contamination by micro-organisms and it is possible that the day-to-day variation in rate of heating up,

encountered with apparently identical fermentations, is in part due to variation in the amount of this contamination.

The experiments were made throughout using Amelonado cocoa packed into 1-litre thermos flasks and an ambient temperature of 30°±1°C. The results of a large number of experiments are summarised as follows:

1. Whole beans removed from the pod without taking any precautions to avoid contamination by micro-organisms or the testas plus pulp from such beans, heated up rapidly with only a brief lag period. At the most this lag period was fifteen to twenty hours.

2. Whole beans removed from the pod under conditions which diminish the amount of chance contamination by micro-organisms gave lag periods of 40–110 hr. before a phase of rapid heating started.

3. Whole beans from which the pulp had been largely removed by washing, or beans from which the pulp and testa had been removed, heated up very slowly and no rapid phase of heating was found in the experimental time of 100–150 hours.

After about 100 hr. the beans from which the testa had been removed were still viable (95 per cent. or more germinated when sown in soil) but fewer than 5 per cent. had germinated. With the washed beans some 90 per cent. had germinated after 100 hours.

HEAP FERMENTATION OF AMELONADO COCOA

Studies at constant ambient temperature

The behaviour of heap fermentations of 5–150 lb. wet weight made in a constant temperature room at ambient temperatures of 30°C. or 35°C. has been studied. This work is still in its early stages and it will be continued during the coming season. The results so far obtained show that with small heaps (5–20 lb.) the temperature-time curve is much smoother than that for similar control heaps fermented outdoors. After the initial rise the temperature of the indoor heaps usually remained approximately constant for about 60–70 hr. and then gradually decreased. The variation in temperature between duplicate small heaps can be considerable but is less with indoor than with outdoor heaps. The assessments of the quality of the cocoa produced in these preliminary experiments is not yet complete.

Effect of covering heaps with polythene

Small heap fermentations are susceptible to partial drying out and also to rapid heat loss in cold weather. Any modification in technique

which reduces losses of moisture and heat should therefore improve the quality of the finished cocoa. For this reason studies have been made of the effect of covering heap fermentations with a thin sheet of polythene. Polythene is almost impermeable to water and water vapour, therefore it diminishes the amount of evaporation of water and at the same time prevents heat losses from this cause. Heaps were built in the usual way and a thin sheet of polythene was placed over them so that the conical surface but not the base of the heap was covered, hence the draining away of sweatings was not prevented. It was found that covered heaps generally ran a degree or two higher throughout the fermentation than uncovered heaps and that drying out round the edges was entirely prevented. Quality assessments have not indicated any overall superiority of the cocoa from covered heaps over that from control heaps. Off-flavours appear to be more prevalent in the cocoa from covered heaps.

Effect of killing the beans by freezing before fermentation

The effect of killing the beans, immediately after removal from the pod, by freezing and then fermenting them has been studied. On the one hand it has been maintained by some workers that if the bean is killed quickly during fermentation then the flavour of the cocoa will be poor, on the other hand there is evidence that fermentation methods which lead to the early death of the bean give a cocoa of good flavour. It was hoped that our experiments would throw further light on this controversy. Also, if it could be shown that killing the beans before fermentation was without adverse effects on flavour then such prefermentation treatment might be a useful step in the fermentation of small quantities of cocoa. Killing the beans by freezing before fermentation should lead to an increase in uniformity since on thawing the chemical changes which commence immediately after the death of the bean would begin in all the beans at the same time. Also, such prefermentation treatment would avoid altogether the presence of slaty beans because, on thawing the frozen beans the contents of the polyphenol storage cells diffuse and hydrolysis of the anthocyanin pigments commences.

Much work remains to be done but the results so far obtained suggest that freezing before fermentation has little effect on the quality of the finished cocoa. Most of the work has been done with batches of Amelonado cocoa of 50–100 lb. using the heap fermentation method, but some experiments have been made with tray fermentations (100 lb.) and also with 1–5 lb. beans by small-scale laboratory methods. Few official assessments are available. The C.S.A.C. panel have reported on the cocoa from a 300 lb. heap

fermentation of Amelonado beans, previously killed by freezing, which they found not to differ in quality or strength of chocolate flavour from a control 300 lb. heap of untreated Amelonado beans fermented at the same time. Both samples were of acceptable quality. A tray fermentation with one of the trays containing 100 lb. of frozen and thawed Amelonado which was dried separately after fermentation also gave cocoa which was considered to have good cocoa flavour and to be indistinguishable from Grade 1 Accra by a continental firm. The C.S.A.C. found this cocoa was acceptable and had the same strength of chocolate flavour as a control from a standard heap fermentation but was slightly inferior in overall quality to the standard.

TRAY FERMENTATION (H. W. S. Allison and R. H. Kenten)

This season 100 ½-ton batches have been fermented by the tray method. Differences have become apparent between the behaviour of the major and minor crops. During the minor crop the temperature rise was appreciably slower than at the height of the main crop and with fermentations of the same duration, cut tests showed a lower proportion of brown beans in the minor crop batches. Whether these differences are due to lower ambient temperatures during the minor crop or to some physiological causes is under active investigation.

So far only a few official assessments of the quality of the cocoa have been made. The general tentative conclusion reached was that fermentations of three to six days duration give a product acceptable to the continental market, but that a six-day fermentation is at the moment preferred by the United Kingdom. Also, while not wishing to commit themselves on the limited number of samples tested, the British Cocoa Scientific Advisory Committee stated that it could be inferred that 'The tray method of fermentation is capable of giving very satisfactory results with Amelonado cocoa'.

Work is continuing on this method of fermentation and attention is being given to varying such factors as batch size, type of cocoa, duration of fermentation and method of drying.

STATISTICS

(C. de Jonge)

The main purpose of this Section is to provide assistance to the Scientific Divisions in the design of experiments and the analysis and interpretation of results. Much work of this nature has been undertaken during the year, and it has been possible to replace some laborious methods of analysis by simpler, non-parametric methods

which have a wider scope of validity. The yield of experimental cocoa trees is usually recorded by counting the number of pods harvested; however, this variable is not normally distributed, and special consideration is being given to the development of a suitable statistical transformation. During the period when cocoa trees are coming into bearing, the yield data are unsuitable for valid analyses of variance, and here again, a suitable transformation is being sought.

IBADAN SUB-STATION

VIRUS RESEARCH

THE CACAO SWOLLEN SHOOT COMPLEX OF VIRUSES OCCURRING IN NIGERIA (J. M. Thresh)

Virus isolates have been taken from some of the many outbreaks of cacao swollen shoot disease which have been discovered in Nigeria. They cause leaf symptoms which show consistent differences in type and severity and they are usually associated with swellings on roots and stem, or on the roots alone. Isolates from widely different localities show the greatest differences in symptom expression. Moreover, they rarely protect against each other which indicates that they are not closely related. By comparison, different isolates from the same tree, outbreak or locality usually protect against each other and cause symptoms which differ in severity but not in type.

This situation with macro-differences between isolates from separate localities and micro-differences between isolates from within them is similar to that already described in Ghana. In each country the most intensively studied isolates can be most conveniently grouped on the results of protection tests and the isolates in each group are apparently closely related strains which show mutual protection, but no relationships with those in other groups.

The differences in virulence between isolates from the same trees and outbreaks make it impossible to recognise the typical isolates from a given locality unless an extensive series of transmission tests are carried out. This has not always been done and in both Ghana and Nigeria isolates have sometimes been given locality names on inadequate evidence. Moreover, they have often proved to be mixed inocula containing both mild and severe strains. This has been demonstrated by single insect transfers from plants graft-infected with many Nigerian isolates. These frequently segregate into strains showing consistent differences in virulence and symptom expression. Consequently the more intensively studied isolates are now being

carried on by repeated single insect passages in an attempt to obtain stable cultures which can be used to increase the precision of subsequent experiments. Both mild and severe strains from Egbeda are now giving consistent symptoms, but with single insect transfers it has been noted that the usual symptoms of the severe strains often fail to appear until the second flush produced after germination.

All previous studies on the strains occurring within swollen shoot outbreaks have been on large ones occurring in areas of mass infection. Consequently it is not clear whether the different strains appear by mutation, segregation from an initial mixed inoculum, or by spread from more than one centre of infection. As an experimental approach to this problem, transmissions are now being carried out to determine the strains present in all the trees within several small, discrete outbreaks found in areas remote from the large centres of infection. Attempts are also being made to determine whether individual mealybugs may simultaneously transmit related strains and how quickly these are resolved on successive passages.

EFFECTS ON GROWTH AS CRITERIA OF RELATIONSHIP BETWEEN ISOLATES OF COCOA VIRUS (J. M. Thresh)

Holmes (*Virology*, **2**, 611, 1956) has recently stressed that unrelated pathogens usually have cumulative effects on their host, when they are inoculated together. By comparison the effect of two related strains is usually intermediate between that due to each one occurring alone. This suggests that observations on the effects of viruses on growth may be used as criteria of relationships and the technique has already been used with cucumber (*loc. cit.*) and ringspot viruses (Harrison, *J. gen. Microbiol.*, **18**, 450, 1957).

The application of the method to cocoa viruses is being investigated with various Nigerian isolates. In the first experiment groups of beans were infected with two isolates of cacao swollen shoot virus from the Egbeda area. These were inoculated singly, and in combination, into beans and the subsequent growth was compared with that of comparable healthy controls. After eleven weeks the Koroboto and Ikire isolates reduced the mean leaf area by 23 and 33 per cent. respectively, when inoculated singly and by 32 per cent. when inoculated together. These results indicate that the two isolates did not behave independently but showed mutual interference. This suggests that they are closely related strains; a conclusion substantiated by the mutual protection demonstrated in conventional superinfection tests. Similar results were obtained in a second experiment with closely related swollen shoot viruses from Ilesha and

Olanla. These protect again each other and reduced leaf area by 29 and 35 per cent. respectively when inoculated singly and by 33 per cent. when occurring together.

Dissimilar results were obtained with the Alaparun isolate of cacao mottle leaf virus and the Koroboto isolate of cacao swollen shoot virus. These reduced leaf area by 22 and 25 per cent. respectively when occurring alone and by 38 per cent. when occurring together. This result was to be expected if both viruses behaved quite independently, and cumulative effects on growth were also noted with isolates of the swollen shoot viruses which do not show mutual protection. For example, the Olanla and Koroboto isolates reduced leaf area by 36 and 50 per cent. when occurring alone and 58 per cent. when occurring together. Similarly the Abuku and Ilaro isolates reduced leaf area by 48 and 40 per cent. respectively when occurring alone and by 57 per cent. when they occurred together.

These preliminary results support Holmes' general hypothesis and effects on growth provide another criterion for assessing the relationships between the numerous isolates of virus which have been made from cocoa. Indeed, the method may well be of greater value than the usual protection tests which give unequivocal results only when the viruses under test cause such dissimilar symptoms that superinfection can be recognised whenever it occurs. The chief disadvantage of the growth tests is that they involve a large number of replicates and substantial insectary space. Furthermore, the inoculations are best done by mealybugs which are inconvenient and tedious for large-scale use.

VIRUS-FREE BUDLINGS FROM INFECTED TREES (J. M. Thresh)

Numberous observations in Ghana and Nigeria show that patches of bark from trees infected with cacao swollen shoot virus do not always infect grafted seedlings. This is usually because the explanted tissues sometimes die at grafting or soon afterwards. However, some patches form a permanent union and persist indefinitely, yet do not cause symptoms. This suggests that they do not contain virus and that this was incompletely systemic in the original source plant. The possibility has already been investigated by Dale (*Rep. W. Afr. Cocoa Res. Inst.*, 1956–57, p. 29) but his efforts to obtain healthy cuttings and budlings from infected clones were all unsuccessful.

In recent work buds were taken from the various branches of large trees at I.N.A. farm which had been experimentally inoculated with a virus originally collected from Olanla. Some of the trees had been inoculated eight weeks previously and had only recently shown

symptoms, which were few in number and restricted to a few main branches. Other trees had been infected for many months and showed conspicuous and extensive symptoms. The grafted plants were cut back to stimulate the buds to develop and one shoot was also allowed to grow from each stock.

All twenty grafts from each of the old infections contained virus, which caused symptoms in the stocks and on all the budlings which developed. By comparison, virus was demonstrated in only some of the patches from each of the recently infected trees. Indeed, budlings have been raised which have not only failed to infect their stock but have made vigorous symptomless growth for twelve months. This strongly suggests that they are virus-free but as a final check they are being cut back and grafted with healthy buds. The new growth will then be kept under close observation for symptoms.

THE EFFECT OF CACAO SWOLLEN SHOOT VIRUS ON TREES

The condition of virus-infected cocoa trees is almost invariably worse than that of adjacent healthy ones (Baker & Dale, *Trop. Agriculture, Trin.*, **24,** 127, 1947; Cope, *Rep. Cocoa Res.*, Trinidad, 126, 1953; Benstead, *Proc. W. Afr. Internat. Cocoa Res. Conf.*, 25, 1953). Indeed, observations in Ghana showed that the most virulent strains caused a drastic decline in the yield of mature trees, which were killed in two or three years (Crowdy & Posnette, *Ann. appl. Biol.*, **34,** 403, 1947; Posnette & Todd, *Ann. appl. Biol.*, **43,** 433, 1955). This has usually been attributed to the primary effects of virus, but insect pests were not controlled in some of the Ghana experiments and it is known that capsids and dieback fungi and possibly thrips build up and cause extensive damage to trees which have been weakened by virus infection (Williams, *Bull. ent. Res.*, **44,** 101, 1953). Moreover, field observations show that infected trees persist longer in favourable conditions than they do elsewhere. This suggests that the deterioration of virus infected trees is at least partially determined by secondary pathogens and environmental conditions.

This possibility can be tested for the first time now that efficient methods are available for the chemical control of capsids and other insect pests. The first experiment was carried out at Koroboto where the spread of a naturally occurring outbreak in peasant cocoa has been followed by regular monthly observations since September 1953 and yield records taken for each of the 827 trees since August 1954. Losses due to black-pod disease have been negligible since fungicide spraying was introduced in August 1955. No valid statistical analysis of the results is possible as positional effects are confounded with other

variables, but the first year's results suggested that virus infection was reducing yield according to the length of time the trees had been showing symptoms. This result was consistent with observations on the condition of the trees, as most of the infected ones were chlorotic with particularly severe capsid damage, defoliation and die-back. A ground vegetation largely consisting of coarse grasses was also invading the plot, which resembled several others in the vicinity similarly affected by capsids and swollen shoot disease.

Routine monthly spraying with *gamma*-BHC, primarily against capsids, was started in January 1956 and the trees have subsequently shown a striking recovery, even though the percentage infection on the plot increased from 24.4 in 1953 to 63.7 in July 1958. Many of the dead branches have fallen and the trees have made extensive new growth from the remaining relatively undamaged parts. Thus the canopy has been largely restored and the ground vegetation has virtually disappeared, while the crops have increased even though regional production declined in the last season. Adjacent farms beyond the drift effect of the spray continued to deteriorate and some have been abandoned and are now being used for food crops.

Several different virus strains occur at Koroboto and they differ in the severity of the symptoms they cause, but typical ones have a marked effect on the growth of seedlings infected as beans in laboratory tests. Thus the yield and growth of infected trees are probably suboptimal and the full benefits of spraying are not being received. Nevertheless, the effect of virus is clearly not lethal on well maintained farms sprayed against capsids, and it is probably no greater than that due to differences in soil, shade or other environmental factors.

The virus strains at Koroboto resemble those occurring in numerous other outbreaks in Nigeria and there is no reason to think that the results obtained there are atypical; indeed similar recovery has already been noted elsewhere. These results are of obvious importance and may influence Department of Agriculture policy in the abandoned areas of mass infection. Further work is clearly justified in Nigeria and Ghana, where particularly virulent strains have been reported. Spraying has already commenced in several other farms and additional work is also planned to elucidate the interaction between cacao swollen shoot virus and the dieback fungus *Calonectria rigidiuscula* (Berk. & Br.) Sacc. on the growth of seedlings and trees growing under different cultural conditions (see p. 71). It is at least possible that the effect of even the most virulent strains, like that of capsids (Taylor, *Tech. Bull.* No. 1, *W. Afr. Cocoa Res. Inst.*, 1954) is largely determined by the shade, soil and other conditions under which attacked trees are growing.

OBSERVATIONS ON SWOLLEN SHOOT OUTBREAKS IN THE ABANDONED AREAS OF MASS INFECTION (J. M. Thresh)

For some years all the trees in several swollen shoot outbreaks in the Ibadan and Ilaro abandoned areas of mass infection have been inspected for virus symptoms at monthly intervals. The information obtained is summarised under the following sub-headings.

Symptom expression

Saplings infected with typical isolates of cacao swollen shoot virus first show transient red vein banding symptoms on the flush leaves, or speckled clearings and angular chlorotic flecks along the minor veins of hardened leaves. Both transient and permanent leaf symptoms intensify on succeeding flushes, but then become restricted to the principal veins as the plants pass into the chronic stage of infection and swellings appear. The sequence of symptom expression on naturally infected mature trees is often similar, although the acute and chronic phases are less distinct. Moreover, it is often difficult to see symptoms due to the poor condition of the trees, their limited growth at certain seasons and the height of their canopy branches. Furthermore, the trees are not all uniform in their reaction to infection and different virus strains may occur in trees within quite restricted areas. Thus it is hardly surprising that there were differences between the symptoms found on infected trees in the field, at the time they were discovered and subsequently.

At each observation plot leaf symptoms were usually the only ones found on trees discovered at an early stage of infection. Symptoms were then often restricted to fan branches produced at periods of vigorous growth. At other times symptoms were found only on the few chupons which were flushing, usually from the base of the tree or the main branches. Leaf symptoms usually became more extensive on subsequent inspections and swellings often appeared. However, the leaf symptoms on some trees were missed until they had already become extensive and in some instances were accompanied by swellings. These appeared, on most of the trees at Offa Igbo, an average of 3.4 months after leaf symptoms had first been recorded. Swellings were also common at Koroboto, but rare on the trees at Ajia, where they did not appear until an average of 11.3 months after mosaic symptoms.

The differences between the plots were partly due to the efficiency with which the trees could be examined for symptoms. At Offa Igbo, the canopy was broken by capsid damage and die-back and most of the living branches could be seen readily, whereas the trees at

Ajia had high interlocking canopy branches and swellings were particularly difficult to see from the ground. Furthermore, transmission tests showed that typical virus isolates from Offa Igbo caused more conspicuous and numerous swellings than those from Ajia. At both plots and at Koroboto some isolates caused severe leaf symptoms and swellings on test seedlings whereas others caused only swellings or mosaic. The mosaic symptoms were sometimes very mild and at Koroboto 10 per cent. of the infected trees seemed healthy at each inspection and only showed inconspicuous chlorotic specks on rare occasions. They were then restricted to the leaves of only a few branches. Even the most conspicuous infections sometimes became almost symptomless, particularly as leaves did not persist long under the relatively open conditions at most of the plots. Furthermore, branches with symptoms were often lost during drought periods or when capsid damage and die-back were particularly severe.

The rate of virus spread

The presence of virus may be demonstrated by transmission tests carried out with mealybugs or grafts, which are difficult on a field scale and unreliable, particularly with symptomless infections. Chemical methods of diagnosis are similarly unsatisfactory and coppicing is the only available method for the large-scale indexing of trees, although it suffers from the disadvantage that it checks spread. Consequently, natural spread can only be followed by observations on the appearance of trees with their first symptoms; an unsatisfactory method further complicated by the variable latent period of infection, ranging from a few weeks to many months and influenced by seasonal factors, the growth and condition of the trees and the ease of symptom detection. Nevertheless, certain trends are common to observations in Ghana, Trinidad and Nigeria.

At each plot the number of infected trees increased annually and followed a sigmoid trend with time. Thus at Koroboto and elsewhere the annual number of apparently new infections increased until approximately half the trees were diseased and then decreased, as infection spread to the edge of the plots. A more realistic estimate of spread was obtained for a longer period when percentage infection was expressed in multiple infection units.

The annual number of new infections is not proportional to the number of existing ones and the ratio between the two decreases with time, suggesting that on this criterion rate of spread decreases as outbreaks increase in size. This is to be expected from the available information on the movement of the mealybug vectors, which is usually for limited distances between the canopy branches of adjacent

trees. Thus mealybugs are unlikely to reach healthy trees from an increasing proportion of the infected ones in an outbreak and most spread occurs from those on the perimeter; particularly as they are likely to be in an early stage of infection and support higher mealybug populations than chronically infected trees.

Rate of virus spread is difficult to compare between plots because of differences in spacing and size and condition of the trees. However, there were considerable differences in the time taken for outbreaks to show similar increases. Thus the number of infected trees at Offa Igbo increased from 50 to 100 in four months and from 50 to 200 in sixteen. Comparable increases occurred at Koroboto in thirteen and twenty-two months, respectively. Virus spread even less rapidly at Iweke where the number of infected trees in a 2-acre plot only increased from thirteen to eighty-four in six years. Even trees in contact with infected ones did not always show symptoms for some years. This situation should be compared with the spread of aphid-borne virus diseases of certain annual crops such as sugar beet, groundnuts or brassicas which may be almost completely infected in a few months.

At each plot the number of known infections did not increase regularly and more infected trees were discovered at certain times than at others. This could indicate peak periods of spread some months previously. However, a more likely explanation is that symptoms were most extensive and conspicuous when the trees were growing vigorously. Thus relatively large numbers of trees were discovered at the main flushing periods in March-April and October-November, at the beginning and end of the rains. By comparison, relatively few infections were discovered in the cool, cloudy conditions of July, August and September, when trees in West Africa make little new growth.

The pattern of virus spread

The pattern of virus spread at each of the Nigerian observation plots was similar to that described in Ghana and Trinidad and most new infections were found alongside existing ones. However, spread was not uniform in all directions from the original source and the outbreaks were irregularly shaped. Furthermore, outlying infections appeared; presumably caused by wind-borne mealybugs. Thus at Koroboto 57 per cent. of the 135 infected trees found in 1954 and 1955 were within 5 yards of obviously infected trees and 88 per cent. were within 20. The corresponding figures for 1956–57 were even higher (84 and 100 per cent. respectively) as relatively few susceptible trees occurred outside 20 yards. The extent of spread between adjacent

trees was probably even greater than is apparent from these data as some sources of infection were symptomless.

The limited spread and steep gradients of infection around swollen shoot outbreaks are consistent with the results of coppicing experiments on the distribution of new infections around other outbreaks in Nigeria. Moreover, they emphasise the importance of local spread by mealybugs moving through the canopy, and give a further indication that the spread of swollen shoot disease into new plantings and plots of mature cocoa can be checked without difficulty, if they are not contiguous with infected trees and are inspected and rogued at regular intervals.

COCOA NECROSIS VIRUS (C. K. H. Martini)

The name cocoa necrosis virus was proposed by Thresh for isolates, from Asalu and adjacent villages in Western Nigeria (*Rep. W. Afr. Cocoa Res. Inst.*, 1957–58, p. 68). These isolates, which have not been experimentally transmitted by mealybugs, produce necrotic symptoms on the first growth of grafted seedlings and transparent lesions on later flushes. Further observations have shown that necrotic symptoms occur frequently on seedlings that are cut back immediately after grafting but only occasionally on seedlings that are left intact. Necrotic symptoms may occur on leaves of the first flush when they are 1–2 in. long or on leaves of the second flush when they are still less than 0.3 in. long. Inoculated seedlings that fail to produce necrotic symptoms may do so after they have been cut back again, provided they survive this treatment.

Shoots with severe necrotic symptoms die but additional shoots develop and grow normally except that occasional leaves show translucent patches along the midrib and sometimes along the secondary veins (permanent leaf symptoms). If the top shoot of the infected seedling has been killed two or more lower shoots may develop simultaneously and these may show narrow leaves as an indirect indication of infection. The first leaves with permanent symptoms may develop two to nine months after inoculation.

Grafting experiments indicate that the occurrence of necrotic symptoms is influenced by the isolate, the distance between the bark patch and the shoot that is left to grow and by the season. Some isolates have produced necrotic symptons regularly between February and October 1958 but failed to do so later, other isolates were never observed to cause necrotic symptoms.

Cocoa necrosis virus occurs in extensive cola-growing areas and trees of *Cola nitida* (Vent.) Schott & Endl. in the outbreak at Omi Aboderin were tested for the presence of the virus. Bark patches from

cola grafted on to cocoa seedlings remain alive for about two to three weeks, some even longer, so that the virus could be expected to move into the test plants. Patches grafted from cocoa into cola seedlings survive for a few days only. Amelonado seedlings grafted with patches from cola in the outbreak at Omi Aboderin and its immediate neighbourhood showed necrotic symptoms very similar to the ones displayed by infected cocoa seedlings. No such symptoms occurred when the cola budwood was taken from trees near Ibadan. Permanent symptoms, however, have so far appeared on single leaves of two seedlings only while the majority of the test plants have remained symptomless during six to nine months after inoculation. The evidence for the susceptibility of *C. nitida* to cocoa necrosis virus is therefore still insufficient.

Some small outbreaks of cocoa necrosis virus, which had been cut out in 1955, were revisited in 1958. The eradication measures seem to have been successful as no new infections on cocoa were found. The only outbreak known to exist at the present time is at Omi Aboderin and has been kept under observation since 1956. The records show an increase of the number of infected trees but it seems doubtful whether this increase is due to spread as several of the trees recorded as infected have shown symptoms only once, and if these trees are excluded the number of infected trees would have been constant for over two years. New observations have therefore been started and they indicate that no new infections have occurred between October 1958 and April 1959.

Experiments on insect transmission of cocoa necrosis virus have included the use of the aphids *Toxoptera aurantii* B.d.F., *T. citricidus* Kirkaldy, the psyllid *Mesohomotoma tessmanii* (Aulm.), the mealybugs *Ferrisiana virgata* (Ckll.), *Pseudococcus njalensis* Laing, *Planococcus citri* (Risso) and some unidentified leaf hoppers and coccids taken in the outbreak at Omi Aboderin. Some of the source plants in tests with mealybugs were infected simultaneously with cocoa necrosis virus and isolates of the swollen shoot or mottle leaf type but no infections have been observed in any of the test plants within three to five months of observation. As the symptoms of cocoa necrosis virus on young seedlings are not known, seedlings between one and eight weeks old were inoculated by grafting with bark patches or leaf tissue but neither group has shown symptoms suggesting an infection after five months of observation.

An experiment has been set up to test the possibility of transmission through the soil or root contact, but no symptoms have occurred during ten months of observation. Pods were collected from infected trees but the seedlings grown from them appeared healthy after five months of observation.

GRAFT TRANSMISSION OF COCOA VIRUSES USING LEAF TISSUE (C. K. H. Martini)

Leaf tissue grafting was first developed by Wallace (*Phytopathology*, **37**, 149, 1947) to transmit certain citrus viruses. His results have been confirmed with two Nigerian citrus virus isolates as sources and lime seedlings as test plants.

One-year-old cocoa seedlings that were cut back after grafting with leaf pieces infected with the isolate from Balogun produced symptoms six to eight weeks later, while seedlings that were left intact showed symptoms five to six months after grafting. Four-week-old seedlings produced symptoms eight weeks after grafting with leaf tissue, and two-week-old seedlings after six weeks. It was impracticable to cut back or defoliate seedlings only four weeks old or less to hasten the development of symptoms as they would usually die if so treated. If pieces of leaf tissue were inserted into radicles of cocoa beans symptoms occurred during the fifth week after grafting.

With one-year-old seedlings leaf tissue proved to be as suitable an inoculum as bark patches but with young seedlings the rate of transmission varied from 20 to 40 per cent. while on beans even fewer transmissions occurred. Only tissue from mature leaves with fully developed symptoms was suitable as inoculum, no transmissions have been obtained with symptomless leaves from infected plants or soft, immature leaves showing the red vein banding symptom.

At the present time the method does not seem as generally useful as in the work with citrus viruses.

INSECT TRANSMISSION STUDIES (C. K. H. Martini)

Nigerian cocoa virus isolates from Balogun, Olanla and Elepo have shown a tendency to develop mild symptoms after several successive transmissions by single insects. From plants showing mild symptoms after one or more transfers of the virus by single insects severe symptoms have been obtained after transfers with five to ten insects. Even if mild symptoms had been obtained after only one or two transfers by single insects and a further three single insect transmissions were made, severe symptoms recurred readily after one or two transfers by five to ten insects. In other transmission series some plants have continued to show severe symptoms after six successive transfers by single insects though the number of plants showing mild symptoms seemed to increase from transfer to transfer.

These experiments have also shown that the Balogun isolate is transmitted by *Pseudococcus njalensis* Laing and other species of mealybug in essentially the same manner as the isolate from New Juaben.

STUDIES ON 'DIE-BACK' OF COCOA

(D. Kay)

Fungi have been associated with most of the die-back examined on mature Amelonado and Amazon cocoa trees grown in the Western and Northern Regions of Nigeria, but some die-back occurred in the absence of fungi. No distinction between these types of die-back can be made from external appearances, but internally it is usual to have well-defined zones of discoloration when fungi are present. *Calonectria rigidiuscula* (Berk. & Br.) Sacc. is considered of most importance because it is the only fungus isolated from die-back that can, under experimental conditions, establish itself and develop in cocoa tissue and produce the field symptoms of die-back. It has been observed that die-back occurs when the ends of branches are damaged as the result of capsid feeding or mechanical injury and the damage being infected by *C. rigidiuscula*. If the infected damage is occluded die-back does not occur, but it is not known what effect this occluded damage has on the chance of subsequent terminal damage leading to die-back. No evidence has been found supporting the contention that occluded lesions can burst out to cause die-back during periods of stress, and there is some evidence against this. In a diseased branch necrotic tissue in occluded capsid lesions has no tendency to increase and merge with the spreading die-back, nor are these occluded lesions greater in size than occluded lesions in non-diseased branches. Similar observations have been made with artificially produced lesions in seedlings. It has been shown that the fungus may enter existing dead wood as a saphrophyte and subsequently attack healthy tissue, thus die-back could form from the damage resulting from exposure to severe drought and Harmattan, and it may be of importance in forming die-back in sun-damaged tissue. It has been shown that shot-hole borer damage is frequently infected with *C. rigidiuscula* but there has been no work to assess the importance of the fungus in contributing to this damage.

It is believed that factors encouraging the regeneration of the tree have some controlling influence on the spread of existing die-back. Age, vigour of the tree, and the incidence of capsid damage affect this spread and in seedlings and mature trees die-back is temporarily arrested when in contact with actively growing tissue. Using an inoculation technique described by Owen (*Ann, appl. Biol.*, **44**, 307, 1956), various factors have been studied in relation to the growth of the fungus in seedlings and mature trees. There was no significant difference between the growth of the fungus in Amelonado and Amazon seedlings. At all times of the year the increase in size of lesions was less in seedlings kept in full sunlight than in similar plants

kept under the shade, when other conditions were optimal for plant growth, but the spread of the fungus in plants in sunlight was more affected by alterations in cultural conditions. The growth of lesions contaminated by various fungi other than *C. rigidiuscula*, was not affected by any change in the cultural condition under which the host was grown. Watering the seedlings with solutions of urea, potassium sulphate, and suspensions of calcium carbonate at varying concentrations, adding sawdust or mixtures of sawdust and calcium carbonate to the soil, or infection of the seedlings with a mild strain of cacao swollen shoot virus from Balogun, made no significant difference to the growth of the fungus in seedlings kept under shade for periods of up to thirty weeks. The growth of fungal lesions was reduced by watering with suspensions of calcium phosphate and was increased when insufficient or excess water was given to the seedlings. Defoliation tended to increase this growth but results were very variable. In sunlight there was a tendency for watering with high concentrations of calcium phosphate, potassium sulphate, and calcium carbonate to decrease the growth of the fungus whilst competition of the host with maize seedlings in the same pot or inadequate watering tended to increase this growth. The effects of watering with solutions of urea, defoliation or adding sawdust and calcium carbonate to the soil were variable.

The growth of the fungus continued inside the seedling after the lesions were occluded externally. There was considerable variation in this growth in different seedlings, and in different parts of the same seedling, e.g. varying if infected at the node or internodally. Growth was always greater in the older tissues. The rate of growth of seedling, chupon and fan tissue varied, but typically there was the greatest growth in the first five weeks followed by less rapid development. No factors have been found affecting the growth of fungal lesions in mature trees.

The growth of these lesions is different in Nigeria from that described by Owen (*loc. cit.*) in Ghana. In addition to the roughly retangular patch of necrotic tissue in the xylem at the site of inoculation, a vertical streak develops at the top and bottom of this patch. There is no apparent difference between streak and patch and *C. rigidiuscula* can be re-isolated from any portion of the necrotic area. After one week's exposure, a lesion is usually composed of a patch 5–8 mm. in length, and streak of 4–40 mm. in length. The proportion of patch to streak is highly variable and it is certain that there is no direct relationship between lesion length and total volume of necrotic tissue. The streak has been found in cocoa tissue of all ages, grown under various conditions.

Owen's technique has given valuable information on the behaviour

of the fungus in cocoa tissue, but it has the draw-back of giving variable results in plants grown under the same conditions, and that the development of the fungus can only be measured by destroying the host. A multiple inoculation technique has been found to produce die-back on mature trees and the die-back spread can be measured without destroying the host. In one field trial, 5 per cent. of the twigs punctured with a sterile needle died back, compared with 85 per cent. of the twigs inoculated with a needle contaminated with *C. rigidiuscula*. There was a direct relationship between the number of inoculations, the size of the inoculated twig and the percentage of die-back. In certain plots a high proportion of the punctures made with a sterile needle became infected with *C. rigidiuscula* and subsequently died back. Further work is required to overcome the difficulties caused by such contamination.

Reducing the reservoir of spores of *C. rigidiuscula* by heavy and frequent sprays of fungicide also reduced the incidence of die-back. Control of capsids by spraying with *gamma*-BHC, and irrigation throughout the year both tended to restrict the spread of existing die-back, and to reduce the incidence of new die-back areas.

ENTOMOLOGY

SHOT-HOLE BORERS (R. G. Donald)

Two experiments involving the application to cocoa seedlings of a urea-formaldehyde lacquer incorporating 10 per cent. dieldrin and 4 per cent. aldrin when dry and of aqueous emulsions containing 0.5 per cent. dieldrin have been carried out at Moor Plantation, Ibadan and at the Agricultural School Farm, at Akure to investigate the effectiveness of these products in controlling 'shot-hole' borers (Scolytidae). At Akure, half of the seedlings were watered during the dry season at the rate of 1 gallon per seedling twice each week. Observations have been made on the effects of these treatments on the incidence of borers and on development of the seedlings.

In preliminary laboratory tests for phytotoxicity it was found that the urea-formaldehyde lacquers caused scorching and blackening of green stems. The damage was only superficial except on very young developing flushes, which were killed. Hardened stems were not obviously affected. For this reason the lacquer was applied only to the lower 12 in. of the plants. Applications were made with a brush in October before the seedlings were planted out at Ibadan, and to plants already growing in the field at Akure. The emulsion was spread on to the stems at monthly intervals beginning in November.

In the Ibadan experiment 480 seedlings were planted in six blocks

of four plots, each of which contained ten Amelonado cocoa seedlings and ten F3 Amazon cocoa seedlings. The insecticidal lacquer was applied to all seedlings in one plot per block and the lower 12 in. of the stems of seedlings in another plot were sprayed with the dieldrin aqueous emulsion. Two blocks per plot were left untreated to give greater accuracy to the analysis of the results in the event of a low incidence of borers.

At Akure 600 seedlings which had been planted during the rains in 1958 to supply vacancies were selected in each of two areas containing progeny of T38 and F3 Amazons respectively. Groups of 200 were split into two blocks, in one of which all seedlings were watered from mid December until late March. These blocks were subdivided into four plots of twenty-five seedlings and the following insecticidal treatments were applied to the different plots:

(*a*) Urea-formaldehyde lacquer to 12 in.
(*b*) Dieldrin emulsion monthly to 12 in.
(*c*) Dieldrin emulsion monthly over all.
(*d*) No insecticide.

In both experiments borer damage was first noted in November before the end of the rains, and increased rapidly until early January. Every boring was of the type made by *Xyleborus morstatti* Hag., though the majority of holes were found to be empty when examined. Adults of this species will attack apparently healthy wood, and after penetrating through the bark and into the xylem, usually turn before reaching the pith cavity and continue their tunnelling in an arc round the latter, a typical gallery taking the form of a question mark when the stem is cut transversely. Copious quantities of sap and mucilage frequently exude from these entry holes when vigorously growing plants are attacked and dead adults are not infrequently found in the galleries, apparently drowned in the liquid. This species is an 'ambrosia' beetle, and eggs, larvae and pupae have been found together with the parent female in one gallery of which the middle of the curved part had been slightly enlarged in a vertical plane. Eggs and, occasionally, larvae were found in a few other galleries, and in all of these a white spongy mass was present, which was believed to be the 'ambrosia' fungus.

Fewer stems were attacked in the plots treated with the urea-formaldehyde lacquer than in the other plots, both at Ibadan and Akure, during the first two months but the degree of control obtained was unsatisfactory (33 per cent.) and was not maintained during the remaining three months during which observations were made on these plots.

At Akure the attack was slightly lower on the watered plots than

on the unwatered ones, but the most significant result of this treatment was found to be the great reduction in the number of seedlings dying or suffering from severe wilt (2.5 per cent. of the watered seedlings and about 70 per cent. of the unwatered ones). Many of the earlier entry holes, particularly in the watered plants, had closed by the time that recording ceased in March and the secondary borers (mainly *Stephanoderes* spp.) which attacked the wilted and dead stems, were absent from those in which growth had continued, even though as many as four or five primary *Xyleborus* entry holes had been made in some of the latter.

OTHER INSECT PESTS OF SEEDLINGS (R. G. Donald)

Coleopterous borers

The Anthribid and weevil species reported a year ago as attacking seedlings in their first and second dry seasons in the field have been identified by the staff of the Commonwealth Institute of Entomology as *Phloeobius* sp. and *Coryssopus* sp. respectively. The former has again been recorded from Ondo Province and from Abeokuta Province, from both of which localised but severe damage was reported in new plantings under moderate to heavy shade. The larvae of this species enter the stem at gound level and bore in a long spiral for a distance of 1–3 in. up into the stem or down into the root, thereafter turning to form another spiral boring in the opposite direction and finally a further spiral back to ground level, at which pupation takes place within the stem. Affected seedlings usually die suddenly during the last stages of larval activity and the stem is so weakened by the attack that the dead plants are easily knocked over. Normally only one larva is found in a seedling, though a double infestation has been seen. A group of hymenopterous parasites have been reared from a single pupa.

Although this species was not uncommon at Apoje in the dry season of 1957–58, it was not found during two visits made recently. It is possible that applications of insecticides, made in the hope of controlling shot-hole borers, may have contributed to this, but it should be remembered that the new plantings are in a different part of the plantation and due to the local distribution of the pest, may have escaped attack for this reason. *Coryssopus* sp. has not been found again.

Damage by Tettigioniidae

Over forty seedlings were found at Akure into the stems of which a long-horned grasshopper had inserted its eggs. These were placed

in five to seven parallel plates per seedling each containing up to fifteen eggs. The incision was usually made a few inches above ground level and penetrated well beyond the middle of the seedling. At the outermost end of each egg there was a ribbon of oöthecal material which protruded from the stem. Over 6 per cent. of the seedlings in one block of 600 in the Shot-Hole Borer Control Trial were attacked in this way, but the plants did not seem to suffer unduly as a result. Several hymenopterous parasites and ten nymphs were obtained from four egg masses brought into the laboratory, but the nymphs died on the second or third day after hatching. Adults have not been observed in the act of ovipositing.

CAPSID CONTROL USING *gamma*-BHC IN KEROSENE (J. F. Longworth)

The method and cost of spraying large areas of cocoa using power driven knapsack mist blowers is fully discussed by Hammond (*Rep. Cocoa Conf., London*, 1957). The overall cost per acre of this method is high and it seems important to reduce this cost while maintaining the efficiency of the operation. C. S. Wishart, Plant Protection Ltd. (unpublished information 1958), suggested that a volatile solvent would offer many advantages over water as a carrier, and trials were carried out to determine the phytotoxicity of such a spray mixture, to determine the effective spray swath width compared with that of the normal water spray, and to find the area of cocoa covered by a measured quantity of the kerosene spray mixture using this swath width. In all the trials the spray was applied at the rate of 1 pint of 'Gammalin 20' in 1 gallon of kerosene, using a 'Motoblo' machine with a size 00 jet.

Fifty seven-month old basket seedlings were sprayed to run off with the kerosene mixture. Some young flush leaves wilted and became blackened between the principal veins. The plants were not permanently affected however, and were soon flushing normally.

A plot of randomly planted mature cocoa was sprayed with the kerosene mixture. The spray in the form of a dense fog, was very finely dispersed and in a light breeze the spray cloud drifted for about 15 yards away from the operator on the leeward side, and about 8 yards on the windward side, and persisted for an appreciable time. The effective width of the swath appeared to be between 15 and 25 yards. In comparison the normal water spray had a much smaller swath width, the spray droplets were clearly visible and the cloud dispersed in a matter of seconds. The plot was inspected a week after spraying and no symptoms of phytotoxicity were noticed. A 16-yard swath width was adopted for future work, as it was felt that a greater distance than this would be impracticable in large-scale use.

A square plot of randomly planted mature cocoa, 1 acre in area was selected. One gallon of kerosene and 1 pint of 'Gammalin 20' were put into the Motoblo and the operator walked through the cocoa rather more quickly than for normal 'Motoblo' spraying. The acre was covered with this quantity of spray mixture, and a further 70 yards walk was needed to empty the machine. A light breeze again affected the spray, the fog persisted in the air, and drifted as a cloud into the adjacent swath. The operation was repeated several times over the area and only an occasional flush leaf showed symptoms of scorch as week after spraying.

Insecticidal activity

A randomly planted 1 acre plot of farmers' cocoa which had been badly blasted by capsids was selected. There was very little canopy, and an extensive ground vegetation. The plot was sprayed in October and November using 16-yard swaths. At the time of the second spraying the trees were already producing a new flush of leaves. On both occasions the spray cloud extended laterally further than the 16-yard swath. Capsid populations were counted on each of eighty selected trees before and after each spray application. An additional count was taken between the two sprayings. Total capsid counts on these occasions are listed in Table 16.

TABLE 16

Counts of capsids on sprayed plots

	Adults	*Nymphs*	*Total*	*Date*
Before 1st spray ..	121	81	202	8.10.58
After 1st spray	0	11	11	10.10.58
Two weeks after 1st spray	1	16	17	29.10.58
Before 2nd spray ..	2	16	18	7.11.58
After 2nd spray.. ..	2	8	10	11.11.58

Recovery of the cocoa since December has been satisfactory.

It has been shown that there is no danger of phytotoxicity at this rate of application. The kerosene spray causes slight irritation to the eyes, nose and throat, and for this reason care is necessary in its use. The lateral dispersal of the spray was satisfactory on all occasions, being greater than that of the water spray, the maximum width being at least 20 yards. The upward movement of the spray into the canopy was as great as that of the water spray. Using a 16-yard swath width, 1 gallon of kerosene with 1 pint of 'Gammalin 20' was used in 1 acre of cocoa. It it is possible in future work to use a cheaper

volatile solvent and a smaller jet, this further reduction in cost, quantity applied per acre, and general transport and labour costs might make this a practical proposition for large-scale spraying of cocoa gainst capsid.

Five 1-acre plots of capsid damaged farmers' cocoa have been obtained at Offa Igbo. Three have received two applications of the kerosene spray mixture as described above, the other two plots have not been sprayed. As part of an experiment at Offa Igbo, three similar plots have been treated with the normal water spray mixture. The condition of the three groups of plots will be observed at regular intervals.

AGRONOMY

(J. F. Longworth)

RAINFALL

The rainfall at Moor Plantation is compared, in Table 17, with the mean for the preceding eleven years.

TABLE 17

Summary of rainfall at Moor Plantation

	Apr.	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
1958/59	1.91	8.93	9.56	0.11	1.91	3.02	9.22	2.79	—
				Jan.	*Feb.*	*Mar.*			Total
				0.03	0.68	2.40			38.56
11 year	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
mean	5.93	6.15	6.67	5.61	3.33	8.15	7.30	2.17	0.36
				Jan.	*Feb.*	*Mar.*			Total
				0.33	0.95	3.59			50·54

CUSHION-GALL

A disease causing galls of flowering cushions on cocoa is causing serious losses in Costa Rica, and is present in Panama and Nicaragua (see p. 20). Galls on flowering cushions have also been discovered on progeny of ICS1, ICS7 and ICS9 cacao at Moor Plantation, and on Amazon cocoa at I.N.A. farm near Ibadan. General descriptions of 'cushion-gall' indicate that the condition is most common on trees which flower prolifically; and this is certainly true in Nigeria.

The gall in its early stages is a proliferating mass of inflorescence tissue, which apparently continues growing until a gall 2–3 in. in diameter is formed. This gall is a warty structure covered with the brown debris of previous flower formation. After the early stages of development the galled cushion produces no further flowers.

There are indications that spread of the condition may have occurred in this plot of ICS cocoa, as there are two discrete groups of five and six trees with large galls, and what appear to be incipient galls have been found on some forty trees between and around these groups.

Attempts to isolate fungi and bacteria from affected cushions have been unsuccessful. A number of young vigorous Amelonado trees have been grafted with cushions from affected trees in an attempt to transmit the condition, and some galled trees have been pollarded.

MANURIAL TRIAL

A manurial experiment was started in April 1958 on an area of yield-recorded, random-planted peasant cocoa at Agodi. The experiment compares the effects of 'N-P' and 'K-Mg' in a factorial arrangement. There were no significant responses to the fertilisers in the first year's crop.

NURSERY TRIAL

The purpose of this experiment is to select a method of producing uniform, vigorous seedlings, more suitable as material for field experiments than those obtained by present practice in Nigeria, which is to grow cocoa seedlings in 'Whalehide' pots closely packed in large nursery beds under heavy shade. The present experiment consists of eighteen replications of a 2^2 factorial layout of fertiliser versus none, and close packing of the 'Whalehide' pots verus a wider spacing. Six replications are placed under each of three levels of shade, *viz.*: no shade, light shade (35 per cent. shade), and heavy shade (65 per cent. shade). Unselected F3 Amazon seeds were planted in a brown friable loamy soil. There are fifty seedlings per plot. An N, P, K, Mg mixture was supplied in solution at the following rates per plant each month: Nitrogen 0.5 g. as urea, phosphorus 0.2 g. as superphosphate and potash 0.25 g. as potassium phosphate, magnesium 0.1 g. as magnesium sulphate.

Growth measurements were made two months after planting and are summarised in Table 18.

Seedlings grew best under light shade, and when they were closely packed. There was no response to fertiliser. There were fewer leaves per plant under shade, but their total area was greatest under light shade. Leaf area was further suppressed by close packing of the seedlings grown under shade, but when un-shaded the close-packed seedlings had larger leaf areas than those that were widely spaced, presumably because they shaded each other to a certain extent.

The seedlings will be grown on in a field establishment trial to

measure any residual effects of the treatments they have received in the nursery.

TABLE 18

Measurements of two-month-old cocoa seedlings

	No Shade	*Light Shade*	*Heavy Shade*
Mean height per plant (cm.)	20.3	25.1	23.0
S.E. of difference = 0.64 cm.			
Mean No. of leaves per plant	12.8	11.5	9.4
S.E. of difference = 0.35 cm.			
Mean area per leaf (sq. cm.)	56.3	70.9	62.2
Mean total leaf area per plant (sq. cm.)	—	—	582.63
Close packing ..	793	740	497
Wide spacing ..	652	884	668
All treatments ..	721	814	583

SEEDLING EXPERIMENTS AT KOROBOTO

The experiments compare healthy F3 Amazon seedlings with ones infected with mild or severe swollen shoot virus and the interactions of treatment with fertiliser, additional watering and super-infection with *Calonectria*. The design is 3×2^3 factorial. The second experiment is similar but the watering treatment is replaced by the comparison of light and heavy artificial shade; a mixture of F3 Amazon and T(N)38 seedlings was used. In both experiments seedlings were graded for uniformity within a replicate and were planted at 3 ft. by 3 ft. Fertiliser was broadcast as a mixture at the following rates:

N—100 lb. N/acre/annum as urea.
P—100 lb. P_2O_5/acre/annum as triple superphosphate.
K—50 lb. K_2O/equivalent/acre/annum as potassium sulphate.
Mg—25 lb. MgO/equivalent/acre/annum as magnesium sulphate.

Shade was supplied by a palm frond canopy. The plants were infected with virus by patch grafting, and *Calonectria* inoculations were made by a modification of Owen's technique (Owen, *Ann. appl. Biol.*, **44**, 307, 1956). Growth records have been taken at regular intervals throughout the year. Fertiliser has exerted a small but consistent depressing effect on growth, but up to January this effect was not significant. No significant response to watering has been detected; at the end of the dry season the watered plants had slightly more leaves than the unwatered ones, but this difference has not been maintained. The effect of virus on growth became significant three months after inoculation.

The results are presented in Table 19.

TABLE 19

Effects of virus infection and other factors on growth of cocoa seedlings

	Mean height per plant (cm.)		
	Healthy Controls	*Mild Virus*	*Severe Virus*
Experiment I ..	95.4	92.4	89.4*
Experiment II ..	85.0	84.1	81.8†
Percentage of seedlings with jorquettes (March 1959)			
Experiment II ..	63.4	59.4	53.8
	Mean height per plant (cm.)		
Experiment II	*Light Shade*	*Heavy Shade*	
	82.6	84.6*	

*P=0.05 †P=0.01

No significant effect of *Calonectria* on growth has been detected; during the dry season plants grew better under heavy than under light shade, but this will probably not continue through the rainy season. In the second experiment virus infection suppressed jorquette formation as well as reducing growth.

When the seedlings are thinned, the *Calonectria* lesions will be measured on the plants removed.

The lack of response to fertiliser was probably due to the limited root development of the seedlings and to leaching of nutrients by rain. Future applications will be made at the beginning and end of the rains. The effect of watering in the dry season was small, and was probably masked by the use of shade and of mulch. During the first three months after planting-out, leaf fall exceeded leaf production.

WEST AFRICAN FUNGICIDES RESEARCH UNIT

(P. O. Park and E. C. Hislop)

On the basis of a programme prepared in April 1958, the unit commenced its studies of the efficiency of a number of fungicides for the control of black-pod disease. During the first year, work of the unit has been largely confined to laboratory studies aimed at evaluating the fungicides in terms of their fungitoxicity, weathering properties, and residual fungicidal effect.

BIOASSAY

It is essential that various levels and forms of fungicide deposit which can be determined chemically should also be assessed biologically. A method was required for testing the fungitoxicity of a

large number of compounds on a specific host, cocoa, to a particular pathogen *Phytophthora palmivora*. Candidate fungicides for field trials might then be limited to those most likely to be satisfactory.

The method of taking sample washings of fungicide deposits and determining the effect *in vitro* was rejected, since it was not possible to remove all, or constant proportions, of the fungicide from known areas of pod surface. Wharton's method (*Quart. Rep. W. Afr. Cocoa Res. Inst.*, No. 46, 1957) of inoculating pods to give multiple infections was then investigated and modified, and a laboratory technique for assessing fungicides was developed.

The procedure is as follows:

Cocoa pods are suspended in 'cages' made of $\frac{1}{8}$ in. brass rod, that are 9 in. high and 4 in. square. It is essential that the pods are not bruised unduly during harvest or transport. The pod, in its cage, is rotated on a gramophone turntable at 33 r.p.m., and is then sprayed with the fungicide suspension at a distance of 30 in. and from a fixed lateral position. An 'Aerograph' Type FN504 precision sprayer operating at 5 lb. per sq. in. is used with a No. 1 nozzle giving an emission of approximately 1 ml. per min. The direction of spray emission is standardised by a pointer attached to the spray nozzle traversing a fixed angular scale.

The sprayed pod is allowed to dry and, still in its cage, is enclosed in a polythene bag with a pad of moist cotton wool to ensure storage in an evenly humid atmosphere. Batches of sprayed pods and of untreated control pods are kept in an air-conditioned room overnight where they become chilled to about 10°F. below the ambient temperature.

Suspensions of zoospores of *P. palmivora* are prepared by washing sporangia from a number of infected cocoa pods into about 200 ml. of water. The sporangial suspensions are allowed to stand for about 45 min. and during this time, in conditions of adequate aeration, most of the sporangia germinate to release actively swimming zoospores. Residual sporangia and mycelial fragments can then be removed by filtration through Whatman No. 1 filter paper or by centrifuging at 1,000 r.p.m. for 5 min.

When the cooled pods are brought from the air-conditioned room and their polythene cover removed, the ambient humidity is sufficient to cause an immediate formation of dew. As soon as this appears, the caged pod is rotated once again on the turntable and sprayed evenly with a suspension of zoospores. A surgical throat spray is used for this, with air from a low-pressure pump. The zoospore suspension must not be sprayed to run-off, and the spray pressure must be low to avoid injury to the zoospores.

The inoculated pods are carefully put back into their polythene bags, and returned to the chilled room. The air-conditioner is switched off, and the temperature of the pods rises slowly to normal, the air within the bags remaining saturated. After four days about thirty lesions will have developed on pods that have not been treated with copper fungicide, and lesser numbers on treated pods. The lesions vary from small water-soaked spots to chocolate-brown necrotic areas some 1 cm. in diameter. An approximately linear dosage-response curve is obtained when the mean number of lesions found on treated pods, expressed as a percentage of those on untreated pods, is plotted against surface deposit on log/probit paper.

Analyses of copper deposits are made on parallel batches of pods that are sprayed with fungicide under the same standard conditions. The deposit is removed by scrubbing with cotton wool dipped in 100 ml. 0.1N H_2SO_4 containing 0.5 per cent. 'Teepol', and with a further rinse with 10 ml. acid/'Teepol', and the copper determined by the method of Martin (*Rep. Agric. hort. Res. Sta. Bristol*, 1956, p. 125). The area of pod surface is calculated by assuming its area approximates to that of a prolate spheroid.

The following broad results were obtained from eight fungicide assessments:

1. The mean number of lesions on un-treated pods was thirty.

2. One commercial fungicide containing cuprous oxide was used as a standard in all the trials. The degree of infection at a variety of difference spray concentrations when plotted on log/probit paper, gave a median toxic spray concentration, for 9 sec. application to pods, of 0.03 per cent. w/v.

3. An approximately linear relation between the deposit on pods, as determined chemically, and the spray concentration, was obtained with this fungicide:

$$d = 5c$$

Where d is the deposit in μg. per sq. cm., and c is the fungicide spray concentration in g. per 100 ml. of water. Thus the median toxic deposit is 0.15 μg. of copper per sq. cm.

4. Attempts have been made, using Kiton Red dye solution and paper cylinders to simulate pods, to assess the evenness of deposits applied from the 'Aerograph' sprayer and to define the conditions which give least variability. The range of deposits on various pods was approximately ± 15 per cent., though different parts of the same pod sometimes showed rather wider variations.

5. The standard cuprous oxide fungicide has been compared with a few other materials. There were indications that two copper oxychloride fungicides were less effective than the standard, a result

compatible with field observations. A cuprous oxide fungicide that had deteriorated during long storage in W. Africa was much less effective than the standard.

PARTICLE SIZE

Sedimentation studies to determine fungicide particle size ranges for a number of products have been made using a pipette sampling technique. The most effective fungicides were found to have a few per cent. of the total copper as particles of less than two microns diameter while less effective formulations had lower proportions. This relationship, if real, would be in keeping with experience in some other fungicide studies.

UNIFORMITY OF DEPOSIT AFTER FIELD SPRAYING

The variation in spray-deposits after routine field spraying, both over the surface of a given pod and also on pods taken from different parts of cocoa trees, was investigated. The copper fungicide residues were determined as described above. Very wide variations were found with a maximum deposit at the tip of the pods. It was not possible to follow the natural weathering of these deposits owing to unseasonably dry weather.

PHYSICAL ASSESSMENT OF INSECTICIDES

The Unit has carried out physical assessment of two 20 per cent. *gamma*-BHC emulsifiable concentrates to find whether they are suitable for capsid control when diluted eighty times with water and sprayed through humidifying nozzles attached to knapsack sprayers. The concentrates emulsified easily and the emulsions were satisfactorily stable. The proportion of fine drifting droplets of emulsion from the humidifying nozzle was as good as or better than that obtained with the standard formulation.

SOUTHERN CAMEROONS

A visit in August 1958 to the Southern Cameroons to study black pod of cocoa and other pests and diseases of coffee and bananas has been reported elsewhere. (Park, P.O. and Hislop, E.C., Rep. on a Visit to the S. Cameroons, W.A.C.R.I., Ibadan, 1958.)

The following papers, giving accounts of work done at the Institute, have been published during the year.

Allison, H. W. S. and Rohan, T. A.: 'A New Approach to the Fermentation of West African Amelonado Cocoa'. *Trop. Agriculture, Trin.*, **35**, pp. 279–288, 1958.

A study of the fermentation of West African Amelonado cocoa has shown that the recommended method employing six days fermentation with mixing after two and four days is by no means the most efficient procedure. It was also demonstrated that this variety can be fermented in as short a time as thirty hours at the surface of a fermenting heap. Having established the principle of rapid fermentation, this was applied on a large scale and conditions have been described for the proper fermentation of half a ton of wet cocoa in two to three days without mixing. Drying of the fermented cocoa can be carried out in the same vessel used for fermentation thus cutting labour costs. Details are given for the relative handling costs in the fermentation and drying of 1 ton of dry cocoa using the standard box method of fermentation, heap fermentation and the new technique, described in this paper for the first time. A new fermentation shed has been designed, and is in process of being erected at the West African Cocoa Research Institute, in which it will be possible to apply this new method of fermentation on a full production scale and it is intended that mechanical aids shall be employed as far as possible to achieve maximum efficiency. On plantations this new system of fermentation should prove more economical than the traditional methods as shown in the results of the costing analyses. The product of this new method of fermentation is superior in external appearance, uniformity, and size of bean; to the cocoa produced by the older methods, and the quality is well within the range of acceptability for West African Amelonado.

Attafuah, A.: 'A brief introduction to the virus diseases of Cacao'. *Ghana Farmer*, **3**, pp. 63–65, 1959.

Brunt, A. A.: 'Leaf enations in Dahlia variabilis Desf. induced by tomato spotted wilt virus'. *Nature, Lond.*, **183**, pp. 627–628, 1959.

Cunningham, R. K. and Lamb, J.: 'Cocoa Shade and Manurial Experiment in Ghana'. *Nature, Lond.*, **182**, p. 119, 1958.

—— ——.: 'A Cocoa Shade and Manurial Experiment at the W.A.C.R.I.'. *J. hort. Sci.*, **34**, pp. 14–22, 1959.

The results of the first year of a field experiment on cocoa in Ghana, involving the removal of shade and the application of

a fertiliser mixture, have shown marked responses both to fertiliser and to the removal of shade. The paper does not suggest that one year's data from a field experiment give sufficient basis for drawing any final conclusions, but the sparsity of published information about the response of cocoa to agronomic treatment, especially in the major producing area for this crop, has caused the authors to report their results.

Rohan, T. A.: 'Processing of Raw Cocoa'. II. Uniformity in Heap Fermentation and Development of Methods for Rapid Fermentation of West African Amelonado Cocoa. *J. Sci. Fd. Agric.*, **9**, pp. 543–551, 1958.

In an earlier publication reference was made to a noticeable difference between the temperatures at the top and centre of heaps of fermenting cocoa. A study of this phenomenon has been extended to a detailed investigation of the lack of uniformity in the rates at which some of the chemical and physical changes, associated with fermentation, occur at different levels in the cocoa mass. A method is described for rapid fermentation of Amelonado cocoa.

Thresh, J. M.: 'The spread of cacao virus'. *Tech. Bull. No. 5, W. Afr. Cocoa Res. Inst.*

——.: 'The control of cacao swollen shoot disease in Nigeria'. *Trop. Agriculture, Trin.*, **36**, pp. 35–45, 1959.

An account and analysis is presented of the work of the Nigerian Department of Agriculture in attempts to control cocoa swollen shoot disease. The decision to abandon eradication measures in two heavily infected areas is partly responsible for the deterioration in the position in recent years. Virus is spreading without check and causing a progressive decline in yield in two abandoned areas, which are acting as dangerous foci of infection. The present situation in the abandoned areas is assessed and an outline given of possible development within them.

The present survey system is described and some of the difficulties experienced by the inspection parties discussed. Details are also given of proposals intended to increase the efficiency of the inspection service, which partly determines the build-up of infection outside the abandoned areas.

The routine measures used in attempts to eradicate virus from infected farms are described and their efficiency assessed. Until 1950 only trees found with symptoms were cut out, and only the smallest outbreaks were eradicated efficiently. Since 1950 the trees found with symptoms were cut out, together with the adjacent apparently healthy trees within 30 yards and virus was eradicated from the cocoa around approximately two-thirds of

the treated villages. However, large numbers of apparently healthy trees were involved and coppicing experiments indicate that comparable success could have been achieved less drastically by treating outbreaks according to their size.

——.: 'Capsids as a factor influencing the effect of swollen shoot disease on cacao in Nigeria'. *Emp. J. exp. Agric.* (in the press).

The unrestricted spread of cacao swollen shoot disease was followed by monthly observations on naturally occurring outbreaks in the Abeokuta and Ibadan Provinces of Western Nigeria. The condition of the trees was more closely related to the incidence of capsid damage and associated die-back caused by *Calonectria rigidiuscula* (Berk. & Br.) Sacc. than it was to virus infection. Indeed, where capsid damage was slight or where it was controlled by spraying, the effect of virus was less marked than that due to other factors influencing growth and yield. By comparison, where capsid damage was severe and not concontrolled, virus-infected trees were worse than their neighbours and often died within a few years. These results emphasise the importance of an ecological 'multifactor' approach to cocoa pests and diseases in their environment.

—— and Tinsley, T. W.: 'Cacao viruses: the world situation'. *Rep. 7th Inter-Amer. Cacao Conf.*, pp. 1–9, 1958.

—— ——.: 'Viruses of cacao'. *Tech. Bull. No. 7, W. Afr. Cocoa Res. Inst.*

Wharton, A. L.: 'The development and application of chemical control methods against black-pod disease' (*Phytophthora palmivora* Butl.) in West Africa. *W. Afr. J. biol. Chem.*, **1**, pp. 111–117, 1958.

Conferences

All of the Senior Staff attended the F.A.O. Cocoa Conference which was held in Accra in February 1959. The following papers were read:

Allison, H. W. S. and Kenten, R. H.: 'Tray fermentation of West African Amelonado cacao'.

Attafuah, A. and Blencowe, J. W.: 'A virus disease of cacao in Sierra Leone'.

Cunningham, R. K.: 'Shade and nutrition as limiting factors in the cultivation of cacao in Ghana'.

—— and Burridge, J. C.: 'Some problems in designing fertiliser field experiments on Ghana cacao and its early years of bearing'.

Entwistle, P. F.: 'Control of cacao swollen shoot vectors; a survey of the problems and recent advances in Ghana'.

Glendinning, D. R.: 'Cacao breeding in West Africa'.

——.: 'Variety trial design'.
Johnson, C. G.: 'The ecological approach to cacao research in Ghana'.
Tinsley, T. W.: 'World survey of cacao virus diseases'.
Wharton, A. L.: 'Black-pod and other cacao diseases of immediate or potential importance in West Africa'.

BALANCE SHEET

AS AT 31st MARCH 1959

WEST AFRICAN COCOA

BALANCE SHEET AS

LIABILITIES

	£	s. d.	£	s. d.
Surplus Account			2,475,101	11 3
Sundry Creditors	6,890	10 6		
Accrued Charges	3,441	4 5		
			10,331	14 11

(Sgd.) JAMES LAMB, *Director.*
(Sgd.) HYWEL LL. PUGH, *Secretary.*

£2,485,433 6 2

We have audited the above Balance Sheet of the West African Cocoa Research
and explanations that we have required. In our opinion and subject to our Report of even
position of the Institute as at 31st March, 1959, according to the best of our information and

Accra,
1st October, 1959

SEARCH INSTITUTE

31st MARCH 1959

ASSETS

	£ s. d.	£ s. d.
LAND AND BUILDINGS—		
Cost to 31st March, 1958	396,187 15 2	
Additions during year	40,390 5 10	
	436,578 1 0	
Less Amounts written off	436,578 1 0	
FURNITURE AND EQUIPMENT—		
Cost to 31st March, 1958	52,359 0 2	
Additions during year	7,505 16 0	
	59,864 16 2	
Less Amounts written off	59,864 16 2	
SUNDRY DEBTORS—		
Staff Advances	16,471 3 10	
Sierra Leone Government	24 7 10	
Western Nigeria Government	240 11 9	
Eastern Nigeria Government	47 6 10	
British Cameroons Government	178 11 11	
W.A.I.T.S.	20 0 0	
Miscellaneous Debtors	2,058 18 4	
Deposits and Prepayments	5,661 7 11	
		24,702 8 5
STORES—At Cost—		
Timber	2,335 5 0	
Fuel	441 0 11	
Maintenance	8,271 14 11	
		11,048 0 10
INVESTMENTS—At Book Value		2,372,115 14 11
(Market value at 31.3.59, £2,041,230 9s. 7d.)		
CASH, BANK BALANCES AND FUNDS WITH CROWN AGENTS—		
Cash on Hand—Tafo	696 19 10	
—Ibadan	3 0 0	
Bank of West Africa Limited—		
Current Account—Tafo	42,041 3 7	
—Ibadan	1,507 2 2	
Deposit Account—Tafo	2,162 2 4	
Savings Account—Tafo	1,131 7 6	
Post Office Savings Bank	4,154 9 9	
Crown Agents—Joint Miscellaneous Fund ..	21,000 0 0	
—Endowment Fund	3,975 0 0	
—Current Account	895 16 10	
		77,567 2 0
		£2,485,433 6 2

stitute with the books and vouchers of the Institute and have obtained all the information te attached hereto, this Balance Sheet sets forth a true and correct view of the financial e explanations given to us and as shown by the Books of the Institute.

(Sgd.) CASSLETON ELLIOT & CO.
Auditors.

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